Middle Byzantine Silk in Context: Integrating the Textual and Material Evidence

by

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ABSTRACT

This work represents the most comprehensive investigation of silk in the middle Byzantine period to date. The current interpretation of silk as an imperial prerogative confined to elite use is poorly integrated with the body of evidence and lacks explanatory value. The difficult terminology and scattered mentions in written sources limits application of conventional research methods. Although a number of silk fragments survive in institutional collections, the lack of find and contextual information represents a formidable obstacle.

This dissertation redefines silk in Byzantium by demonstrating its social importance, contribution to technology development, and integration in the regional economy. Findings are based on intensive analysis of production and consumption data from parallel investigation of texts and textile fragments according to a common framework. To aid data collection and analysis, information technology tools involving relational database methods and digital imaging were devised for this purpose. The evidence suggests that the historical process involving silk was shaped by a continuing cycle of elite differentiation and imitative reproduction, which contributed to the transmission of the material and production in the region. From a broader perspective, this work demonstrates the relevance of textile studies to the interpretation of economic and social history.

DEDICATION

To my family for all of their support

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At the outset of this project, John Peter Wild provided helpful advice on research approaches and introduced me to some professionals in the field. The technical analysis presented in this work owes much to Chris Verhecken-Lammens' expertise. In my visits to Katoen Natie in Antwerp, I learned about structural attributes that are not well documented in the literature through first hand observation. Discussions concerning some textiles included in this work further contributed to my knowledge.

In developing the research methodology for this project, I had the benefit of microscopy training and equipment suggestions from Gary Laughlin and Sebastian Sparenga at the McCrone Research Institute. I would like to thank Nathan Ilnicki and the staff at Hirox USA for help in defining equipment appropriate for high resolution imaging of historic silks. Application of computer vision tools for characterisation of ancient textiles was a core requirement of this project. At the University of Birmingham, David Pycock and Chang Su developed an initial methodology for textile image analysis based on my initial requirements. At Oakland University in Rochester, Michigan, Nilesh Patel and his team of engineers including Jie Ouyang, Andrey Semenov, and Michael Flynn developed computer vision algorithms required for this application according to my specifications. Michael Flynn's work was instrumental in integrating these tools with the user interface into a coherent application.

At the outset of this project, a visit to the Whitworth Art Gallery collection initiated my search for a new research approach methodology for historic silks. My thanks to Frances Pritchard for introducing me to the famous Bock collection at the museum. At Dumbarton Oaks, I am especially grateful to Gudrun Bühl, Stephen Zwirn, and Marta Zlotnick for their generous assistance during my two research visits. I would like to thank Howard Sutcliffe and Michael Kociemba for allowing me access to the textile collection at the Detroit Institute of

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ABBREVIATIONS

AI	Ars Islamica
AJA	American Journal of Archaeology
ARAM	ARAM Periodical
Atex	Ars Textrina
BAI	Bulletin of the Asia Institute
BCH	Bulletin de correspondance hellénique
BM	British Museum
BMFA	Museum of Fine Arts Boston
BMFD	Byzantine Monastic Foundation Documents: A Complete Translation of the Surviving Founders' Typika and Testaments
BMGS	Byzantine and Modern Greek Studies
BNBC	The Bulletin of the Needle and Bobbin Club
BNJbb	Byzantinisch-neugriechische Jahrbücher
BOC	The Book of Ceremonies
BOE	The Book of the Eparch
BS	Byzantinoslavica
BSOAS	Bulletin of the School of Oriental and African Studies (London University)
Bur Mag	The Burlington Magazine
BZ	Byzantinische Zeitschrift
CFHB	Corpus Fontium Historiae Byzantinae
CHNYC	Cooper-Hewitt, National Design Museum
CIETA	Centre International d'Etude des Textiles Anciens
cm	centimetre(s)
CMA	Cleveland Museum of Art
CSHB	Corpus Scriptorum Historiae Byzantinae
DIA	Detroit Institute of Arts
DO	Dumbarton Oaks Research Library and Collection
DOP	Dumbarton Oaks Papers
EHB	The Economic History of Byzantium
EI	The Encyclopaedia of Islam
JESHO	Journal of the Economic and Social History of the Orient
JMedHist	Journal of Medieval History

JNES	Journal of Near Eastern Studies
JÖB	Jahrbuch der Österreichischen Byzantinistik
JRSA	Journal of the Royal Asiatic Society
Kelsey	Kelsey Museum of Archaeology
KTN	Katoen Natie
LBG	Lexikon zur Byzantinischen Gräzität
MGH	Monumenta Germaniae historica
MMA	Metropolitan Museum of Art
MünchJb	Münchner Jahrbuch der bildenden Kunst
ODB	The Oxford Dictionary of Byzantium
OHBS	The Oxford Handbook of Byzantine Studies
RBPH	Revue Belge de Philologie et d'Histoire
REB	Revue des études byzantines
REG	Revue des études grecques
REI	Revue des études islamiques
SAAHT	Scientific Analysis of Ancient and Historical Textiles: AHRC Research Centre for Textile Conservation and Textile Studies. First Annual Conference 13-15 July 2004
SMB	Staatliche Museen Zu Berlin
Spec	Speculum
TAPA	Transactions and Proceedings of the American Philological Association
Teubner	Bibliotheca scriptorum Graecorum et Romanorum Teubneriana
TexHist	Textile History
TM	Travaux et mémoires
TMA	Textile Museum of America
TRJ	Textile Research Journal
um	micrometre
V&A	Victoria and Albert Museum
Yale	Yale University Art Gallery

Note on transliteration

Transliteration of Greek words is based on the spelling used in the *Oxford Dictionary of Byzantium*. Transcription of Arabic names and words follows the system employed by the *Encyclopaedia of Islam*.

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CHAPTER 1 - INTRODUCTION

1.1 Silk Characteristics and History

This work represents the most comprehensive investigation of silk in the middle Byzantine period undertaken to date. The objective is to redefine historical understanding of the material by demonstrating its social importance, contribution to technology development, and integration in the regional economy. Findings are based on extensive analysis of production and consumption evidence from textual sources and surviving textile fragments. Contrary to the prevailing view of silk as an imperial prerogative confined to elite use, this research shows that silk had a larger role in the material culture of middle Byzantine society and was important to cross cultural economic and social exchange.

From a historical perspective, the favourable characteristics of silk differentiated it from other natural fibres. Its rich and luxurious associations belie its ignoble source as the protineous excretion of the silkworm *Bombyx mori*.[1] During the first millennium, silk became the most desirable fibre in the Mediterranean region. The material's westward spread from East Asia to the Mediterranean through long-distance trade was a major factor in cultural and economic exchange among distant civilisations.[2]

Early accounts considered silk to be a novelty. Its properties and versatility were soon recognised, stimulating demand.[3] Silk is highly receptive to dye compounds, so is capable of producing brilliantly coloured fabrics. Its triangular fibre shape reflects light, resulting in a

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[1] For the properties and processing of *Bombyx mori* silk, see Currie 2001; Datta and Nanavaty 2005; Lee 1999; Hills 1993; Cook 1984, 144-165; Grayson 1984, 451-458; Zhao, Feng, et al. 2007; Sonwalkar 2001. For scientific analyses of historic *Bombyx mori* textiles see Becker and Tuross 1993; Becker, Magoshi, et al. 1997; Greiff, Kutzke, et al. 2005; Garside and Wyeth 2002.

[2] Loewe 1971; Young 2001, 14-15; Hansen 2012, 235.

[3] Yates 1843, 160-251; Forbes 1964, 50-58; Wild 1970, 26-27.

rich and lustrous finish. Fine diameter yarns allow patterns to be woven with high resolution, while long fibre lengths make fabrics smooth and pliable with a graceful drape. Silk is light in weight, durable in various climatic conditions, and tolerant of dense packing. Most importantly, its mechanical properties, which combine strength and elasticity, provided the basis for development of new weaving technologies.

Over time, silk became more than just a luxury good confined to elite members of society. Unlike some types of materials with limited practical applications, silk is suitable for a wide range of uses including garments, hangings, furnishing, and bindings. Demand for silk spawned development of new agricultural products in the region, notably sericulture to rear cocoons, and moriculture to provide the quantity of mulberry leaves required to feed silkworm larvae.[4] Expanded access to fibre and demand for silk cloth stimulated progressive developments in processes and technologies.[5] Essentially, silk provided the material basis for several long-term developments. In economic terms, the material contributed to trade, commerce, and development of new occupations and industries.[6] The role of silk in society is evident from accounts of its consumption and integration into the material cultures of the region. Increased demand stimulated silk production, and the cycle continued.

While the expansion of silk production and consumption in the region is widely acknowledged, specific features of the industry's development are more difficult to discern. Chroniclers had little reason to document silk manufacturing processes, and producers were not inclined to record or publicise their trade secrets. Apart from the Cairo Genizah,[7] few

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[4] For moriculture and sericulture in Byzantine history, see chapter 2.1.
[5] Geijer 1979, 96-102; Becker 1987, 81; 253-261.
[6] For occupations and professional workshops associated with silk, see chapter 4.
[7] The Cairo Genizah refers to the trove of discarded writings recovered from the Ben Ezra Synagogue at Fustat (Old Cairo). For a summary of contents, see Goitein 1967-1993, I, 1-28.

commercial documents involving silk processes and trade have survived. Historical knowledge of silk comes mainly from accounts of its consumption in a variety of forms and contexts.

1.2 Silk Evidence in Primary Sources

The existence of silk in Byzantium is documented in various primary sources. In the early period, a series of laws concerning silk were issued beginning in the fourth century. Over time, the state restricted the material through manufacturing and usage prohibitions. In the middle Byzantine period, the two most elaborated sources associated with silk date from the tenth century. The *Book of the Eparch* (*BOE*) (911/12) is a collection of regulations applied to guilds under the supervision of the eparch of Constantinople.[8] The eparch functioned as the governor of the city and was responsible for juridical and administrative matters.[9] The *Book of Ceremonies (BOC)*, attributed to Emperor Constantine VII Porphyrogennetos (945-959), is a compilation of fifth- to tenth-century protocols used by court officials to stage imperial rituals.[10]

Together, these sources have shaped much of the existing Byzantine scholarship pertaining to silk. The *BOC* describes silk in a wide variety of imperial contexts where it was employed to project a complex and overlapping set of meanings. Highly choreographed processionals communicated order, stability, and hierarchy to onlookers.[11] Silk garments provided a means to convey status and position through a defined hierarchy of dress. The imperial investiture ceremony signified the sanctity manifest in the silk chlamys as an article

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[8] For analysis of guild regulations, see chapter 2.4.
[9] *BOE*, Koder, 20-41; Guilland 1980.
[10] *BOC,* Reiske. See chapter 2.2 for ceremonial use of silk.
[11] McCormick 1985, 19.

of insignia.[12] Receptions were calculated to demonstrate the power and opulence of the state through displays of technology and sumptuous decorations.[13] The emperor bestowed valuable silks in promotional ceremonies, as salary payments, and to reward distinguished service.[14]

The structure and content of the *BOE* has contributed to the notion that silk was a monopoly, or at least extensively controlled by the state as an imperial prerogative.[15] Among the twenty-two regulatory chapters in the *BOE*, five pertained to the silk industry.[16] Outright prohibitions for non-imperial consumption included use of murex dyes and production of certain types of textiles.[17] The attributes of prohibited fabrics coincide with accounts of imperial silks described in the *BOC*, demonstrating correspondence between the two sources.

In addition to written sources, representational images in various media displayed luxury textiles as a means to project imperial status and power. In mosaics and illuminated manuscripts, the sumptuous appearance of garments and attention to fine detail convey the impression of silk. Imperial portraits showed heavily decorated textiles with rank communicated through various attributes. The silks portrayed in representations coincide with middle Byzantine written descriptions.[18] For example, the mosaic above the imperial doorway in Hagia Sophia depicted an emperor in a chlamys, patterned to simulate silk, making *proskynesis* before the enthroned Christ.[19] A tenth-century ivory carving showed Christ

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[12] *BOC,* Reiske, I: 38, 196-199. For a description of the role of the chlamys in imperial costumes see Parani 2003, 12-18.
[13] *BOC,* Reiske, II: 15.
[14] *BOC,* Reiske, I: 44, 227-229; 45, 229-231; II: 44, 661-662; 45, 668-669. Also see *Imp Exp*, C.225-260, 501-511; for textiles as payments see Hendy 1985, 191.
[15] For example, see Lopez 1945, Muthesius 1995b.
[16] For an analysis of the silk chapters in the Book of the Eparch, see chapter 2.4.
[17] *BOE*, Koder, 4.1, 4.8, 8.1, 8.4.
[18] For depiction of imperial costume, see Parani 2003, 11.
[19] See appendix 1.1, fig. 1. The emperor was not named, but is most often identified as Leo VI (886-912). For an analysis of this mosaic in the visual language of gift giving, see Brubaker 2010.

placing a crown on the head of Emperor Constantine VII Porphyrogenitos who was wearing a heavily decorated *loros* over a *divetesion* carved to show the drape of silk cloth.[20] The Psalter of Basil II (976–1025) presented the victorious emperor in a brilliantly coloured silken tunic with a gold border.[21]

Among the valuable textiles most 'visible' to us through description, silks woven with representational figured patterns tend to dominate our impressions. The *BOC* described the large silks hangings in the Chrysotriklinos.[22] Representational patterns portrayed imperial symbols such as lions, griffins, mounted riders, peacocks, and eagles. The *Imperial Expeditions* treatise described silks with heraldic motifs as gifts from the emperor to senior military officials and foreign dignitaries.[23]

Silk production was not recorded in the Christian West until the twelfth century, so luxury fabrics were imported there from eastern domains.[24] Manufacture of high quality silks in Muslim Spain is also documented in numerous Islamic sources.[25] The *Liber Pontificalis* included precious textiles among inventories and donations in the eighth and ninth centuries. Among the hundreds of valuable textiles recorded, several were described with figurative motifs including lions, elephants, griffons, tigers, peacocks, and eagles.[26] Brubaker analysed figured silks recorded in the *Liber Pontificalis* between 730 and 850.[27] While the fibre type

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[20] See appendix 1.1, fig. 2.
[21] See appendix 1.1, fig. 3.
[22] *BOC,* Reiske, II: 15, 581-588.
[23] *Imp Exp*, C.239-242, 251-253, 501-508.
[24] For example, see *Nik Chon,* Dieten, 73-76, esp. 74, 40-49; 98, 43-49; *G. Fri*;*G. Frid*, XX 370, 29-36. Also see Jacoby 1991-1992, 462-463 n. 54-55; Sabbe 1935a, 818, 830, 833, 835-837.
[25] For a survey of sources concerning silk in Muslim Spain, see Serjeant 1972, 165-176; Constable 1994, 173-181.
[26] *LP*, Duchesne, 12, 29, 57, 75-77, 82, 107-109, 114, 120-121, 130, 145, 194. Also, see Michel 1852, 14-17; Starensier 1982, 216.
[27] Brubaker and Haldon 2001, 80-108, esp. tables 1 and 2, 104-108.

and source were not consistently described, contextual clues aid in discriminating mentions of figured cloth. In addition, Greek textile terms were occasionally carried over to Latin inventories in transliterated form.[28]

Other European sources provided ample evidence for imported precious silks. In the *Vita Karoli Magni,* Einhard described the splendid fabrics endowed by Frankish ruler Charlemagne (768–814) to the church at Aachen.[29] According to an entry recorded in the *Gesta pontificum Autissiodorensium*, Bishop Gualdric (918-933) gave a lion silk to St. Eusêbe, Auxerre with the Greek inscription 'during the reign of Leo, the Christ loving ruler'.[30] In the mid-1800s, Michel compiled hundreds of references to luxury silks and metallic cloths beginning in the sixth century that convey the impression of wide circulation in the region.[31] In his study of medieval mentions of valuable textiles, Sabbe demonstrated both the quantity and quality of fine cloths imported during the Carolingian period and later.[32]

Among the luxury textiles depicted in representational works, several portrayed figured patterns similar to those described in written works. The portrait of Nikephoros III Botaneiates (1078-1081) and his courtiers displayed garments with a variety of woven repeating patterns. Although now badly deteriorated, one attendant is dressed in a robe with a large roundel-inscribed figured design.[33] The portrait of Alexios I Komnenos (1081-1118) in *Vat. Gr.* 666, f. 2r depicted the emperor in a patterned chlamys receiving a treatise from church fathers.[34] An enamelled icon, now in Berlin, portrayed Saint Demetrios wearing a

[28] Brubaker and Haldon 2001, 83-84.
[29] *V. Karoli*, 31.26.
[30] G. d'Auxerre, 44.213.
[31] Michel 1852.
[32] Sabbe 1935a, 811-825.
[33] For an illustration, see appendix 1.1, fig. 4. Literary descriptions of figured silks with representational designs are discussed in chapter 4.4.
[34] See appendix 1.1, fig. 5.

figured chlamys while standing on a decorated dais.[35] A number of middle Byzantine church paintings in Cappadocia display apparent woven designs. Writing about the dress of borderland elite, Ball counted repeating roundel designs, a characteristic motif of Byzantine silk design, on seventeen donor portraits in the region.[36]

Complementary to literary and representational evidence for figured silks are hundreds of textile fragments attributed to Sasanian, Byzantine, and Islamic workshops held in museum collections, and religious institutions.[37] These were recovered from church treasuries, shrines, tombs, and cemeteries. Fine silks were highly valued in medieval Europe and were used for liturgical and reliquary purposes. In the late nineteenth and early twentieth centuries, non-scientific excavations in Egypt led to the large-scale transfer of remains to the antiquarian market. Irrespective of whether silks came from shrines or excavations, the large majority lack contextual information. All survive in fragmentary form in various states of conservation.

Among the figured silks attributed to Byzantium, four bear inscriptions that support workshop attribution and dating between the ninth and eleventh centuries. The largest and most impressive piece is the eleventh century 'imperial elephant' silk recovered from Charlemagne's tomb, and is now housed at Aachen Cathedral.[38] The inscription on this piece suggests that it was woven at a state workshop located within the Imperial Palace complex.[39] The remaining three textiles have a striding lion motif arranged in vertical rows down the length. Known collectively as the 'imperial lion' silks, these fragments have formulae which

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[35] See appendix 1.1, fig. 6.
[36] Ball 2005, 64, pls. 2, 6, 11.
[37] For example, see Desrosiers 2004; Muthesius, 1997; Martiniani-Reber 1986; Stauffer 1991; Schmedding 1978.
[38] Vial 1961; Muthesius 1997, 183.
[39] Muthesius 1995f, 65; for the inscription and analysis see chapter 2.3.

differ in the rulers named.[40] The Krefeld portion of one inscribed ‘imperial lion’ silk that had been divided among three museums was apparently lost during World War II.[41] Surviving pieces are now held in Berlin and Düsseldorf. The imperial silks have been technically analysed, but only Muthesius has reported her observations of the entire group.[42] To date, no epigraphic study has been published, nor has there been an analysis of the specific methods used to weave the inscriptions.

Although the body of material attributable to the imperial workshop is small, the inscribed silks represent evidence concerning textile production methods. In addition to their striking visual appearance, surviving figured silks are important to textile history because of the scale and complexity of their patterns. The technical term for the structure used to produce these fabrics is weft-faced compound weave.[43] The technology applied to this structure relied upon separation of the warp into two functional units. The binding warp bound inserted weft yarns into a coherent cloth. The main warp was manipulated independently to create a weft design on the textile face.

The weft-faced compound weave figured silks attributed to the imperial workshop were woven on sophisticated drawlooms.[44] These devices were equipped with a figure harness for repetitive production of woven patterns. Although the origin and development of these looms

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[40] See Muthesius 1997, 34-38. Siegburg lion silk: ‘during the reign of Romanos and Chistophoros the Christ loving rulers’, Constantinople, 921-923; Cologne lion silk: ‘during the reign of Basil and Constantine the Christ loving rulers’, Constantinople, 976-1025; Krefeld-Berlin-Düsseldorf silk: ‘during the reign of Constantine and Basil the Christ loving rulers’, Constantinople, 976-1025.

[41] Muthesius 1997, 35.

[42] Muthesius 1997, 34-43. For the ‘imperial elephant’ silk, see Vial 1961; for the Siegburg lion silk, see Brachwitz 2002; for the Cologne lion silk, see Wilckens 1991.

[43] CIETA 2006, 43. See the glossary included as appendix 1.2 for a glossary of technical weaving terms included in this work.

[44] CIETA 2006, 15; CIETA 1987, 16-24.

is obscure, they were important labour-saving devices.[45] Patterns tied-up in a figure harness provided a means of recording and storing work for later mechanical reproduction. Without a means to replicate memorised patterns, weaving designs in silk was slow and tedious. Drawlooms and associated weaving technologies permitted production of figured silks in the quantities required for imperial purposes.

1.3 Research Approaches

Historic textiles can be studied from various disciplinary frameworks including anthropology, ethnology, economics, sociology, archaeology, history, and art history. Investigations can yield valuable information from a number of perspectives including: social hierarchies, trade, agriculture, technology development, and artistic expression.[46] During the past century, a sizeable literature has developed to interpret surviving fragments and to place them in historical context. Figured silks attributed to Byzantium have been studied principally in terms of art history, textual analysis, and technical weave structure.

a. Art historical

The most extensive contributions to the scholarly literature concerning silk have been from an art historical perspective. The scale and contrast of pattern designs and quantity of surviving material make representational analysis an obvious method of investigation. The main objective is to interpret the symbolic and narrative content from a defined cultural and

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[45] See chapter 6.1 for the use of drawlooms to weave figured silks.
[46] For discussion of various research approaches applied to textiles, see Weiner and Schneider 1989, 1-29.

historical framework.[47] Areas of study relevant to textiles include subject matter and degree of emphasis in motifs, use of space, symmetry, colour choice, and value contrast.[48]

Tracing developments in the field, early studies in the late nineteenth and early twentieth centuries were preoccupied with ornamentation and aesthetic choices in the presentation of repetitive motifs.[49] Catalogues were the main vehicles for presenting textiles, with most commentaries limited to descriptions based on categories of content. Examples included classical themes, vegetative motifs, animals, birds, hunting scenes, mythological subjects, and Christian iconography. Publications directed toward an antiquarian readership contributed to the wider appreciation of patterned Byzantine textiles as both works of art and important historical artefacts.[50]

Beginning in the 1920s, figured silks were treated more analytically based on iconographic and stylistic interpretations. Ebersolt's 1923 study of the imperial art of Constantinople remains relevant today for its synthesis of luxury goods production, including textiles.[51] Kitzinger's 1946 essay on figured textiles explored the extent to which stylistic classification could be correlated with materials and technique.[52] Grabar investigated the influence of eastern artistic styles and technology on the luxury arts of the Macedonian period (867-1081).[53] Subsequently, he published a detailed analysis of the Gunther imperial silk tapestry.[54]

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[47] Sonday 1988, 14.
[48] Sonday 1987, 72.
[49] See chapter 5 for the historical progression of scholarly approaches to figured textile remains.
[50] Examples of descriptive publications include Gilman and Gilman 1922; Bunt 1967.
[51] Ebersolt 1923.
[52] Kitzinger 1946, 3.
[53] Grabar 1951.
[54] Grabar 1956.

An essay by Beckwith on Coptic tapestries sought to establish stylistic progression from Hellenic to Christian themes.[55] His 1961 book on Constantinople included silks among the material arts produced in the imperial city.[56] A subsequent study of Byzantine silks divided the material into pre- and post-Islamic conquest categories in an argument for continuity of tradition.[57] His approach was based on categories defined by characteristics such as motif, style, colour, and weave type.

The first full-length studies devoted to selected 'imperial quality' silks appeared in 1982. Starensier's dissertation investigated the historical role of silk in Byzantium.[58] This analysis evaluated textual and representative evidence to construct a contextual interpretation of figured textiles. Muthesius surveyed Eastern Mediterranean silks in Western treasuries and collections.[59] The goal was to look beyond stylistic evidence to include weave structure and technical processes in developing a chronology of Byzantine silk textile production. Her 1997 book represents the most complete survey of Byzantine silks published to date.[60] Muthesius is credited with efforts toward cross-disciplinary investigation and consideration of some structural weave attributes. Importantly, this work brought unpublished material to the attention of Byzantine historians. However, Muthesius' basis for dating silks has not been verified by scientific methods.[61]

Various scholars have explored the influence of textile patterns on other representative media. In a study of late antique ornament, Gonosová examined silks as the source of

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[55] Beckwith 1959.
[56] Beckwith 1961.
[57] Beckwith 1974.
[58] Starensier 1982.
[59] Muthesius 1982.
[60] Muthesius 1997.
[61] See chapter 5.7 for objective dating methods.

repetitive surface patterning in other media including mosaics and architectural sculptures.[62] Maguire analysed the repertoire of designs on domestic textiles from Byzantine Egypt as charms to deflect evil and bring good luck.[63] He also discussed some imitations of more costly luxury goods including floor mosaics made to look like expensive marbles, ceramics for repoussé-like decoration of metalware, and wool tapestries woven to simulate the symmetrical designs of drawloom silks.[64] Other scholars have considered the appropriation of Sasanian textile motifs into the Byzantine visual sphere as evidence of cultural interaction and adaptation. Brubaker suggested that Sasanian motifs known from stucco reliefs, metalwork, and frescoes entered the Byzantine repertory through the medium of silk and later spread to other media.[65] She also noted that shared images and long use complicate dating and attribution.

Treatment of costume within art history is a specialised field in its own right. Work by several researchers has demonstrated how Byzantine textiles were employed as garments. Piltz documented some of the garments described in the *BOC*.[66] Dawson presented an analysis of imperial costume combined with practical perspectives on the structural attributes of some garment types.[67] Parani examined Byzantine art as a source of material culture information about furnishings and imperial, official, aristocratic, and military forms of dress.[68] Woodfin demonstrated that late Byzantine embroidered liturgical vestments were derived from middle Byzantine court dress. He argued that vestments not only served as a

[62] Gonosová 1987.
[63] Maguire 1990.
[64] Maguire 1999a, 242-243.
[65] Brubaker and Haldon 2001, 91.
[66] Piltz 1997.
[67] Dawson 2002.
[68] Parani 2008, 11-158, 179-185.

vehicle to project the liturgy, but also reflected the Byzantine worldview with earth as a reflection of the heavenly sphere.[69]

The most significant factor inhibiting progress in the field is the lack of a secure basis for dating. While figural representations on textiles offer a rich body of material, fragments are too poorly situated temporally and geographically to support specific conclusions. The literature of the field includes examples of speculative attributions. Grabar associated the 'Charioteer' silk with the victory celebration held after the pillage of Zapetra in 837, an assertion that has been challenged elsewhere.[70] Similarly, Beckwith described the 'Imperial Elephant' silk as a reflection of the Abbasid tastes of Emperor Theophilos (829-842).[71]

The advantage of an art historical approach to textile pattern analysis is that it can integrate evidence from a variety of media including sculpture, mosaics, ceramics, coins, seals, and illuminated manuscripts. Unlike textile fragments, many of these sources can be securely dated. For textiles woven with memorised pattern reproduction, a strictly art historical approach without reference to the technology of production can also be problematic. The constraints imposed by the loom on the form and presentation of mechanically reproduced designs have often been overlooked in analyses concerned with motif and its development.

b. Textual analysis

As compared with research centred on representational analyses of figured silks, less attention has been devoted to textual studies. Beginning with Du Cange, most of the earliest works were written by philologists who sought to interpret the challenging terminology

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[69] Woodfin 2012.

[70] 'Charioteer' silk: V&A T.762; Grabar 1971, 58; Also, see Brubaker and Haldon 2001, 81-82.

[71] Beckwith 1974, 348-349.

associated with textiles.[72] Reiske's commentary on the *BOC* remains an important reference for historians in studies involving luxury fabrics.[73] Philological studies by Schmitter for silk and Georgacas for linen synthesised evidence from a variety of written sources to demonstrate the evolution and development of terms based on fibre content.[74] Schmitter noted that while terminology studies can recognise the incidence of various words, there is seldom sufficient descriptive information in written works to form a reconstructive view of textiles.[75] He concluded that a historian must have both a strong understanding of technique and rigorous training in textual analysis.[76]

In 1945, Lopez published the first comprehensive scholarly work focused on the Byzantine silk industry.[77] Although now dated, this pioneering essay remains an influential resource for study of the legislative and regulatory framework for silk and state control of the private industry. Simon, Vryonis, and Maniatis each have studied private silk guilds in Constantinople.[78] Using seal evidence, Oikonomides presented a controversial interpretation of fiscal officials known as the *kommerkiarioi* and their role in the silk trade.[79]

Jacoby has undertaken the most comprehensive treatment of Byzantine silk to date in a series of essays. In his 2004 historical cross-cultural examination of silk, Jacoby noted that most scholarship has been based on a highly selective body of material centred on elite textiles.[80] To balance the imperial focus of most scholarship, he sought to place the material

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[72] Du Cange and Carpentier 1733; Du Cange 1943.
[73] *BOC,* Reiske, II.
[74] Schmitter 1937; Georgacas 1959.
[75] Schmitter 1937, 201.
[76] Schmitter 1937, 201.
[77] Lopez 1945; Muthesius 1995b; a history of silk in Byzantium is presented in chapter 2.
[78] Vryonis 1963; Simon 1975; Maniatis 1999.
[79] Oikonomides 1986; for a more detailed discussion see chapter 2.1.
[80] Jacoby 2004, 197.

within a broader social and economic context.[81] Another work demonstrated the emergence of an eleventh-century silk industry in the western provinces of the empire in response to expanding demand.[82] A study devoted to the period 1330-1380 analysed evidence for sericulture in Morea and Venetian Messenia.[83] By integrating western and Byzantine sources, Jacoby's work demonstrated the importance of silk to the economic history of the region.

While not exclusively devoted to silk, a number of works contain information relevant to textile production activities. Professional textile workshops were mentioned in sources dating from late Roman through late Byzantine periods. Diocletian's *Edict on Maximum Prices* issued in 301 contains extensive references to commercial textile activity including professional production activities, specialist textile occupations, and transportation patterns.[84] Other documentary sources, such as papyrus letters from the same period, indicated various types of professional cloth processing activities.[85]

A distinction is drawn in this work between professional workshops and domestic production. Byzantine writing contains many references to women spinning, weaving, and making cloth in their households.[86] Even the highest born women were expected to produce textiles, as noted by Michael Psellos' criticism of Empress Zoe Porphyrogenneta (1028-1050).[87] Although men were weavers by occupation, in the domestic sphere, spinning and

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[81] Jacoby 2004.
[82] Jacoby 1991-1992.
[83] Jacoby 1994b.
[84] *Diocletian*, chapters XX.12; XXII.6, 7; XXIV.16; also, see Graser 1940. For discussion of textile production, see Wild 1987; Wild 1970, 9, 13, 37.
[85] Bagnall, Cribiore, et al. 2006, 71, 352-357, especially *P. Oxy*. 14.1679, *P. Oxy.* 31.2593; Wipszycka 1965.
[86] See Talbot 2001, 126-127, 130; Kazhdan 1998, 16.
[87] *Psellos,* Renauld, IX.159, 3-5.

weaving were exclusively female occupations.[88] Contemporary writings projected the normative view that cloth making was an appropriate domestic activity for women.[89] While a significant degree of overlap occurred between domestic and market-based production sources, the specialised skills and organisational resources required to weave complex figured silks meant that these cloths were woven in a professional setting.

c. Technical analysis

Use of ancient textiles as a source of technical weaving information began in the mid-nineteenth century in industrial cities in Europe and North America.[90] Materials recovered from archaeological or religious contexts were combined into collections in several manufacturing centres. Museums made textiles available to the public to inspire design and elevate popular taste.[91] Studies at the time were principally devoted to decoration without extensive reference to specific weaving techniques.

In the early decades of the twentieth century, historic textiles were gradually recognised as a source of technical production information. Researchers devised various methods of analysis to study the relationship of cloth components to each other and to consider the techniques and equipment involved in the process of construction. During the 1920s, 1930s, and 1940s, studies by Flanagan, Kendrick, Pfister, Bellinger, and others provided a foundation for the field.[92] Progress was hindered by the lack of common methods and terminology to compare textile analyses among different collections. The approach devised by Guicherd became the basis for the Centre International d'Étude des Textiles Anciens (CIETA)

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[88] For a discussion of the social identity of professional weavers including gender, see chapter 2.3.
[89] Laiou 2001, 264-265.
[90] See chapter 5.5 for discussion of developments in technical analysis.
[91] Martiniani-Reber 1986, 7.
[92] Flanagan 1919; Kendrick 1925; Pfister and Bellinger 1945.

method of analysis.[93] While the CIETA method is now recognised as a common basis for reference and comparison, the majority of textiles in institutional collections have not been documented from a technical perspective.

The body of technical analysis performed during the past half century has demonstrated a progression of weaving technologies and methods in the Near East and Mediterranean regions. Studies of complex figured silks have documented various categories of weaves on technical grounds. Based on technical and representational analyses, scholars have attributed a number of silks to Byzantium in studies prepared by Müller-Christensen, Vial, D'Adamo, Martiniani-Reber, Jerusalimskaya, and Linscheid.[94]

While adoption of a common lexicon and analysis methodologies has helped to advance historical understanding of weaving technologies, definitive attribution has proven to be more challenging than was probably anticipated when CIETA was launched in the mid-1950s. More than fifty years of technical scholarship has demonstrated the cosmopolitan nature of textile production with extensive cross-cultural exchange between various Mediterranean and Near East weaving centres. However, development of a definitive basis for technical attribution has remained elusive.

Several factors have hindered progress in the field. The majority of published analyses were confined to a single or small group of textiles with little cross-functional or inter-institutional collaboration. The specialised literature and lack of synthetic studies have meant that technical research concerning silk has not been integrated into broader scholarship. In practical terms, the unintended consequence of high conservation standards to protect fragile

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93 Guicherd 1946; CIETA 1957; CIETA 1979; CIETA 1987.

94 Müller-Christensen 1960; Vial 1961; Jerusalimskaya (Ieroussalimskaja) 1966; D'Adamo 1979; Martiniani-Reber 2004; Linscheid 2012.

material for future generations is that complex silks are nearly inaccessible for detailed study. Given budgetary constraints, few public institutions have adequate resources to support research. At present, the field is effectively at a standstill, with no deliberated plan to apply technical analysis methods for attribution.

1.4 The Byzantine Silk Narrative

The cross-cultural character of silk in Persian, Byzantine, and Islamic histories and the methodological tools of various related disciplines, as discussed above, have made integration difficult. Consequently, the collective body of surviving evidence has been only superficially considered. Lacking a framework for critical analysis and synthesis of the wider population of references to silk, imperial-focused sources are predominant in the literature. Essentially, the coherent point of view provided by prescriptive texts and the state's success in projecting meaning through silk has shaped research approaches. Close identification of silk with the empire has been reinforced by selective consideration of textile remains. The result over time has been the formation of a Byzantine silk narrative familiar to historians and textile researchers.

With some variations, mainly in emphasis, the Byzantine silk narrative can be summarised as follows. From the time sericulture technology arrived in Byzantium in 553/4, silk remained under state control as an imperial 'monopoly'.[95] While the source of raw silk is undocumented, some authors have proposed that the empire was largely self-sufficient, effectively comprising an autarky, at least until the Islamic conquest of the Levant region in the seventh century.[96] In the early and middle Byzantine periods, silk was an imperial prerogative and was controlled by the state. High quality silks were woven at the imperial

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[95] Dagron 2002, 444.
[96] Lopez 1945, 12; Muthesius 1995c, 328; Oikonomides 1986.

workshop in Constantinople, although a closely restricted private industry also existed. By inference, access to silk was confined to the most elite members of society.[97] New production centres, such as Thebes and Corinth, are known to have developed only later, and are first documented in the twelfth century.[98]

During the past seventy years, this narrative has become a fixture of Byzantine studies and has been propagated through published works over time.[99] Several histories of medieval Europe include a version of the Byzantine silk narrative in discussions of regional economic and social developments.[100] Various museum catalogues, textile studies, and general publications relay a condensed version of this narrative.[101]

Considered from an imperial perspective alone, the Byzantine silk narrative appears to be a reasonable interpretation of material culture. Yet, closer examination suggests discontinuities that leave many questions unanswered. As a framework for analysis, the conventional view has numerous shortcomings and limited value in the study of historic processes. The silk narrative is a remnant of a now dated notion of Byzantine society as a tradition-bound state theocracy that operated through complex and rigid canonical codes. During the past half century, the field of Byzantine studies has undergone dramatic reappraisal with recent attention to themes such as continuity and change in society, the role of appropriation and exchange, and changing relations with neighbouring cultures on its

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97 Brubaker and Haldon 2011, 479-480.
98 Jacoby 2004, 202 n. 26.
99 For example see Lopez 1945, Muthesius 1995f; Muthesius 1997, Muthesius 2004; Oikonomides 1986; Starensier 1982; Beckwith 1974.
100 For example, see Hodgett 1972, 113-127; McCormick 2001, 719-728. Many secondary works on related topics refer to the Byzantine silk industry. See Sanders 1994, 31, 151; Jenkins 2003, 325-330; Hann and Thomas 2005, 59-61; Lui 1996, 73-91.
101 For example, see Martiniani-Reber 1986; Trilling 1982; Harris 1993, 75-79.

borders.[102] From the standpoint of contemporary scholarship, the Byzantine silk narrative requires reconsideration through application of current research methods and standards for critical analysis.

Collectively, the nature and type of evidence available to us reveals certain problems with current approaches. The first of these pertains to our understanding of silk as an imperial prerogative. Brubaker observed that textiles are poorly understood in the context of Byzantine society.[103] The larger question is whether silk was an exclusive material confined to a small elite population or more broadly available in middle Byzantine society.

The Byzantine silk narrative also neglects the consequence of status projection through luxury goods and its implications over time for collective behaviour. A prevailing view is that luxury goods occupied a visible, but rather limited, role in the material culture of Byzantium.[104] Textual sources suggest that a value hierarchy of textiles existed with conventions for use. Repeated prohibitions prompt questions about the exclusivity and extent of private ownership of silk. Sumptuary laws and controls implied that the material was accessible enough to spur imitation and reproduction. While this process has been accepted over a long timescale, we have only a limited understanding of the imitative use of silk in Byzantium and its role in the development and spread of textile technologies.

Looking beyond imperial sources, the subject of Byzantine trade and commerce has garnered significant attention during the past decade with a number of symposia and publications.[105] Yet, as Carrié has observed, ‘It is hardly comprehensible why the importance

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[102] For example, see Cameron 1987, 107-109; Haldon 2009.
[103] Brubaker and Haldon 2001, 80.
[104] For example, see Cutler 2002.
[105] For example, see Mango 2009; Morrisson 2012, Kislinger, Koder, et al. 2010; Laiou and Morrisson 2007; Laiou 2002.

of textile production, from the point of view of its impact on economy and manpower [sic], has been undervalued and neglected, or even simply ignored'.[106] Indeed, contemporaneous Islamic and Jewish sources clearly demonstrate that textiles were a major industry in the greater Mediterranean region. Trade in textile raw materials and finished goods was so extensive that Goitein devoted much of his work on the Cairo Genizah to discussion of the 'textile economy'.[107] While the documentary basis for the Byzantine textile trade is fragmentary by comparison, valuable evidence of commercial activity has survived in a number of texts.

One of the most problematic aspects of the conventional narrative is how to define and identify silk as 'Byzantine'. Textual descriptions lack technical details describing distinguishing attributes of finished goods as well as the source of fibre and place of manufacture. Between the seventh and the thirteenth centuries, silk was an international industry comprising a series of regional circuits linked through long distance trade. The industry encompassed materials at various production stages, each with different characteristics and market participants. Trade in silk overlapped related industries, notably those involving dyestuffs and processing materials.

Workshop attribution based on surviving textile fragments is equally problematic and remains an on-going problem in scholarship. Although a relatively large number of silks survive, few collections have been comprehensively published. The result has been a bias toward the most impressive and intact pieces. Some silks have been extensively published with at least some documentation of technical characteristics. However, the field lacks defined parameters that characterise Byzantine silks and distinguish the material from the

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[106] Carrié 2012, 18-19.
[107] Goitein 1967-1993, 1:101.

products of other workshops.[108] After decades of scholarship, silk finds from Egypt are still conventionally attributed to Byzantium while all other textile finds are classified as Coptic.[109]

A large factor complicating research is that silks are among the most fragile of material survivors. The high conservation standards necessary to protect fragments make the materials difficult to access for study purposes. In practice, the opportunity for detailed inspection of silk fragments is available to only a handful of specialists. Even then, textile evidence is difficult to understand and interpret. Significantly, the lack of quality illustrations, technical analyses, and cross-collection documentation has meant that current scholarship does not fully reflect surviving evidence. The result is that our understanding of silk textile use in Byzantium has remained static, lacks connection with other attested evidence, and seems divorced from the broader regional context.

A final problem pertains to the lack of an organising framework to advance research in the field. Ideally, once scientific dating has been established, attribution should be based on a combination of representational and technical textile analysis. However, apart from some piece-specific analyses, there are few examples of extensive collaborations, even within a single collection. This gap is noteworthy in comparison to analyses of Islamic textiles where several collaborations have produced important scholarship.[110]

1.5 Research Objectives

To provide a framework for broader consideration of silk in Byzantium, I have defined a set of three research requirements. The first is that investigation of Byzantine silk requires

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[108] Brubaker and Haldon 2001, 80.
[109] Thomas 2007, 137.
[110] For example, see Kühnel and Bellinger 1952; Glidden and Thompson 1988; Glidden and Thompson 1989; Fluck and Helmecke 2006.

balanced treatment of evidence. Middle Byzantine sources need to be interpreted comprehensively to gather internal evidence. To provide a more secure historical basis for silk research, other types of writing in addition to imperial-focused sources should be considered including histories, chronicles, and testamentary documents. The literature of neighbouring cultures also provides relevant information.

A second requirement is to define a methodology appropriate to the nature of the evidence. Most historical studies have approached the silk industry in aggregate, with references to silk fibre, woven materials, and finished goods co-mingled. The silk industry in the Mediterranean and Near East comprised a number of distinctive products at various processing stages with different markets and usage characteristics. Evidence concerning the bulk trade in silk fibre differs greatly from attested end use for finished goods. Consequently, an analytical approach to the subject needs to be structured in terms of relevant categories defined by production stage and use. A structured approach is particularly important because much of the evidence comes from scattered textile mentions from a number of written works. Although fragmentary and incidental, some mentions contain specific evidence that is meaningful when considered in terms of usage patterns.

A third requirement involves definition and selection of research techniques to support a detailed, cross-functional interpretation of surviving material. As bodies of evidence, surviving silk fragments and written information have widely differing characteristics. From a practical perspective, the specialised resources required to examine one type of evidence precludes detailed consideration of the other. Consequently, most studies are devoted either to evaluation of remains or to textual analysis with the other form considered anecdotally. The challenge is to define a research approach that supports broad and coincidental consideration of evidence.

This assessment of needs provides a basis for defining the purpose and specific research questions addressed by this work. My overall goal is to obtain a more comprehensive understanding of Byzantine silk in context by exploring the material in terms of production and consumption characteristics. The focus of my research involves three related topics: the social role of silk in the middle period, the attested hierarchy of valuable fabrics, and the integration of Byzantium within the regional textile economy.

The first objective is to investigate the broader role and social importance of silk in the material culture of the middle Byzantine period and how it developed over time. From the earliest recorded accounts, silk was prominent in literary sources as a luxury product. The material signified elite status and symbolised wealth and power. Expensive garments and furnishings provided a means of conspicuous display. Less well studied are the specific features and attributes that made silk important in its contemporary setting, and differentiated the material from other textile fibres.[111] Attested usage patterns and textile evidence show that the social role of silk was not static. The material was adapted and integrated into society in various ways.[112] Over time, the collective behaviour of consumers altered patterns of production and consumption.[113] Considered this way, silk provides an example of the dynamic role of certain elite goods in material culture.

Among silk textiles, sources indicate that a relative hierarchy of valuable cloth existed. By the middle Byzantine period, the use of silk fibre alone was not enough to designate elite use, and other attributes became important such as dyes, precious metals, and applied

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[111] See chapter 4.2 for properties that differentiated silk from other fibres.
[112] Chapter 8.3 discusses the social role of silk and the hierarchical ordering of elite goods based on textual and textile evidence.
[113] See chapter 8.3 for the role of patterned silk weaves in the regional economy.

embellishments.[114] A second objective of this study is to assess the consequence of competing efforts to differentiate luxury goods for elite use from more common products and imitative reproductions. Production of complex, drawloom-woven figured silks provided a technological means of limiting reproduction, while at the same time permitting scale production for elite and ceremonial use.

The third objective is to establish the extent of Byzantium's integration into the regional textile economy. A major shortcoming of the Byzantine silk narrative is its focus on the empire to the exclusion of neighbouring cultures. Yet, evidence shows that textiles were exchanged through various channels including diplomacy, war spoils, population movements, and trade. This analysis explores imitation and reproduction as a factor contributing to the consumption and production of silk and the spread of weaving technologies.

1.6 Methodology

I have defined the structure of this project in terms of my research purpose and the nature of the surviving material. The challenge is to identify a means to interrogate evidence critically in a form that can be synthesised for comparative analysis. The approach I have devised relies upon collection of specific data with analysis based on quantitative methods.

In recent decades, new research methodologies supported by computer information technologies have equipped historians to analyse evidence more exhaustively and dynamically than in the past. A variety of research tools are now available to aid in organisation and classification of data in ways that identify connections and patterns associated with historical processes. The goal is to obtain a more coherent understanding of textiles in context by aggregating data from a variety of sources. In effect, this project

[114] For discussion of the attributes that distinguished high status silks, see chapter 4.4.

represents a feasibility test of the proposed methods and their applicability to the study of Byzantine silk textiles.

The main problem is to define a methodology that supports direct comparison of textual descriptions with textile remains. In written works, textile descriptions vary depending upon an author's interest, knowledge, and purpose of recording. All textile survivors are fragmentary with little or no contextual information. To provide an objective basis for analysis, data gathering and analysis must be structured in terms of characteristics common to both types of evidence. A methodology structured in terms of production stage provides a common organising framework. The four production stage categories applied to both textual mentions and silk remains are: material, textile characteristics, pattern, and finished goods. Each of these categories includes evidence for quality decisions and planning.

a. Textile mention database

A survey of Byzantine, Islamic, and Jewish sources dated between the sixth and twelfth centuries reveals a large number of textual 'mentions' describing textiles.[115] These mentions appear in a wide variety of works and are often incidental in nature. Most mentions contain only partial information, but include some specific details such as production place, materials, weave type, end use, design, quality, and usage context. The low information content of each mention limits the amount of data that can be gathered through conventional textual analysis. The research problem is to define a methodology to organise and assess fragmentary information in a consistent way.

To accomplish this task, I developed a database of textile mentions similar in concept and form to a prosopography. This data management tool provides a means to assemble

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[115] A methodology for collecting and analysing textile mentions is described in chapter 3.

widely distributed information into a consolidated resource. I designed the database to analyse details about textile attributes while retaining contextual information about processes, exchange, and use. The resulting corpus provides an evidentiary basis to discern patterns that are difficult to perceive with conventional methods. This tool for data analysis provides a basis for more comprehensive consideration of written evidence.

b. Computer vision analysis

Analysis of textile fragments requires a different set of tools to extract meaningful information in a way that can be analysed and compared with written evidence. The advantage of textiles is that they are composite structures created through a series of processes. Woven line by line, fabrics provide a sequential record of production. A consistent methodology is required to discern technical details from extant fragments and to define relationships among sets of distinguishing characteristics.[116]

From a practical standpoint, the collections access policies now in place at most museums mean that investigative methods must be strictly non-invasive and conservation safe. During the past decade, dramatic advances in imaging technologies have made digital photographs the medium of choice for recording technical textile attributes. However, the fine resolution of silk textiles requires specialised microscopy equipment to capture consistent, high quality images at a scale appropriate for objective characterisation.

An additional technical problem is that much of the production data embedded in textiles exists at a level that is too diffuse to be captured reliably by conventional measurement methods. Computer-based technologies can aid in developing low-level data into meaningful information according to scientific research standards. Within the field of

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[116] A methodology for analysing textile fragments is presented in chapter 6.

computer engineering, computer vision refers to technologies associated with acquiring and using information from digital images. My research programme combines digital imaging with use of computer vision software tools for analysis purposes.

The common feature of both research methodologies is that they are designed for empirical investigation of related data sets. While source data are fragmented or diffuse, consolidation into a corpus supports comparative analysis and detection of patterns that are otherwise difficult to perceive. To take full advantage of these methodologies, written information and technical textile data are each analysed independently according to the production-based framework described above. The results from each body of evidence are then considered collectively. By systematically interrogating the evidence, this project provides a methodology for intensive data analysis within the limits of source evidence.

1.7 Scope and Significance

Given the enormous quantity of potential source material, this work required a well-developed research plan and explicit definition of research parameters. Considerations in interpreting texts include the purpose of a work, an author's knowledge and point of view, and the date of writing. Textile fragments must fit the defined research protocol and be accessible for study purposes. An attempt to cover all surviving evidence is well beyond the scope of this work, and would represent a daunting challenge. Instead, my aim has been to identify a set of materials that comprise a significant sample of the larger populations. Given the differences in source material, research parameters vary by evidence type. Methodological issues associated with textual sources are discussed in chapter 3 with problems associated with textile analysis described in chapter 6.

As conveyed by written works, textile raw materials and finished goods were traded extensively through various channels in the Mediterranean region. To obtain an understanding of the role of Byzantine silk in the regional textile economy, this work draws upon contemporary Islamic and Jewish sources. No silks in the collections surveyed for this work include textiles attributed to Christian European workshops before the twelfth century, although a few pieces are assigned to Islamic Spain. Since this work is developed from a production point of view with a focus on the interaction of supply and demand, European texts are not included in the textile mention database analysis presented below.[117]

Many middle Byzantine sources discuss textiles in one form or another, but not all refer to professionally woven silks. For the purpose of this study, I analysed the major historical works that cover the fifth to the thirteenth centuries. To avoid selective consideration of evidence and to place silk into context, I recorded all textile mentions from each source included in the corpus. The intent was to define the main body of evidence related to silk with the potential to add more data from additional sources in the future.

During the middle Byzantine period, a number of different weaves involving silk were probably in common use including tapestry, tabby, twill, and complex structures. The choice of weave was determined by both the technology employed and intended use. The large majority of archaeological silks attributed to Mediterranean and Near East workshops are weft-faced compound weave figured silks, commonly known as taqueté (tabby binding) and samite (twill binding).[118] These structures were the dominant means of mechanically reproducing monochrome and coloured patterns in cloth until the development of lampas

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[117] See chapter 4 for analysis of the textile mention database.
[118] See chapter 6.1 for discussion of the structural attributes of weft-faced compound weaves.

weaves in the twelfth and thirteen centuries.[119] Unlike simpler structures, taqueté and samite contain several technical parameters for evaluation. Given the nature and incidence of surviving evidence, all of the textile fragments analysed in detail are weft-faced compound weave silks attributed to Mediterranean and Near East workshops.

Within the field of Byzantine studies, the aim of this research programme is to provide an expanded basis for discussion of silk and its role in the material culture. The intention is to interpret the material in a way that is both accessible and meaningful to the broader community of scholars. The social process of elite differentiation and imitation of luxury goods provides a heuristic framework of potential value to economic and social historians. For art history, this research brings a more informed perspective to interpretation of textile designs and better definition of technical characteristics for integration with representational analysis.

As a cross-disciplinary study, this research programme benefits the field of textile history in several ways. One important contribution is to demonstrate the role of textiles in the larger historical process. From a methodological standpoint, this project provides a specific empirical basis for measurements of complex weave silks. It also serves as an example of how the use of digital representations in artefact research can aid in the examination, analysis, communication, and interpretation of artefacts. Ideally, the imaging methods developed for this project can support increase participation in a field that is now limited to a few institutions and individuals.

[119] For the development of lampas weaving technology, see Schorta 1997.

1.8 Structure

I have structured this work to examine written and physical textile evidence in parallel fashion beginning with a historical summary which describes how the form of the evidence has shaped research approaches to date. The next set of chapters present research methods appropriate to the characteristics of surviving evidence. Each section concludes with data analysis according to a common framework comprising: materials, textile production, pattern representation, and end use. The conclusion in chapter 8 integrates the written and physical evidence based on the common framework used for data analysis. This work concludes with recommendations for a research programme to advance the study of silk textile remains.

In Part I: Chapter 2 - Silk in the Middle Byzantine Period traces the history and developments associated with silk in the empire through the twelfth century. The various ceremonial, diplomatic, and economic roles ascribed to silk are discussed, concluding with evidence for private production and trade. Chapter 3 - Textile Mention Database Methodology presents the research approach developed to gather textile mentions into a relational database. The chapter begins with a review of the Islamic, Jewish, and Byzantine sources included in this work. Prosopography is examined as a relevant model for structuring a textile mention database, followed by definition of guidelines for interpretation of evidence. Chapter 4 - Textile Mention Data Analysis discusses research findings from more than 800 textile mentions drawn from twenty-two Byzantine primary sources. The chapter opens with attested terminology, followed by silk fibre analysis and textile processing information. Evidence for various types of compound and figured weaves is presented, followed by an analysis of consumer preferences associated with end use.

The chapters in Part II are framed around the surviving silk fragments found in ten museum collections in Europe and North America. Chapter 5 - Technical Analysis of Textile

Remains presents the history associated with surviving silk fragments. Major topics include development of technical research methods and the current framework for attribution. This chapter concludes with a discussion of the current research environment for figured silks. Chapter 6 - Computer Vision Research Methodology defines a new approach to characterise detailed silk production evidence using high-resolution digital images and software tools to aid in objective analysis. This chapter includes a description of the technical attributes common to weft-faced compound weaves. Chapter 7 - Computer Vision Data Analysis presents my analysis of data obtained from more than 10,000 digital images of 125 silk textile fragments. Consistent with the analysis framework applied in chapter 4 for the textile mention database, data are analysed in terms of materials, textile characteristics, pattern production, and end use.

PART I: CHAPTER 2 - SILK IN THE MIDDLE BYZANTINE PERIOD

To provide a historical and institutional framework, this chapter opens with a review of silk as an imperial prerogative in early Byzantium. By the eighth to ninth centuries, the material had become an important imperial resource, with a complex set of ceremonial, diplomatic, and economic roles. A state silk workshop produced the textiles required for imperial use. Close consideration of source material provides evidence for the workshop's fiscal administration, location, and the social identity of workers. Despite official legal prohibitions, a private silk industry developed in Constantinople. In the tenth century, production and sale of non-imperial goods was regulated by the eparch of the city. Economic and social changes in the eleventh and twelfth centuries influenced both the production and consumption of silk in the Byzantine world.

2.1 Historical Development of Silk

Chinese legend credits a third-century BC princess with the discovery of filament silk drawn in continuous lengths from caterpillar larvae.[1] The traditional tale holds that a silkworm cocoon fell from a tree into the princess' cup of tea, whereupon the hot liquid loosened silk fibres from the gum binding. Archaeological evidence confirms ancient silk cultivation in early China. The earliest depictions of silkworms are carved into an ivory basin attributed to the Neolithic culture of Hemudu (ca. 5000-3000 BC).[2] The oldest identifiable silk remains are dated to the middle of the fourth millennium BC and were found in Henan province in north-central China.[3]

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[1] Chang 1986, 215-216; Kuhn 1988, 247-250.
[2] Vainker 2004, 22.
[3] Vainker 2004, 22.

Throughout history, *Bombyx mori* has produced the only domesticated variety of cocoon capable of reeling. The silkworms described by Aristotle, and later Pliny, probably referred to varieties of wild silk from other genera in the family *Bombycidae*.[4] Unlike cultivated silk, wild varieties are coarser in texture and need to be spun to form yarn. Although wild silk has been used in textile production throughout history, it is rare in surviving textiles attributed to the Mediterranean region.[5]

The extent to which silk was traded with the West is unknown until about 115 BC when Mithridates II of Parthia made an alliance with Wu Ti, the Han Emperor of China, to facilitate trade.[6] The flow of silk into the Mediterranean region was spurred by growing prosperity in the Roman empire and stable political conditions along the principal caravan routes. Until AD 224, the Parthian empire controlled most of the Chinese silk trade with the West.[7] When the Sasanian and Byzantine empires were established in the third and fourth centuries, trade along the Silk Road was active and relatively secure.[8]

Silk initially arrived in the West in the form of finished cloth. Pliny described how imported Chinese silk fabrics were unravelled and rewoven into a light gauze cloth.[9] The *Periplus Maris Erythraei* indicates that regular trade in silk fibre also occurred in the mid-first

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[4] *Hist Anim*, 5.19; *Pliny*, 11.26. For a summary and analysis of silk mentions in antiquity, see Forbes 1964, 50-58; Broughton 1938, 823. Other silk varieties include *Antheraea* (tussah and muga silk) and *Philosamia* (eri silk).

[5] For example, see Vial 1985, 50-55.

[6] Thorley 1971, 71.

[7] Bentley 1993, 33. For discussion of western sources for the overland silk trade, see: Young 2001, 190-198.

[8] Bentley 1993, 33. The term 'Silk Road' was first applied by Ferdinand von Richthofen to depict information taken from Chinese dynastic histories into a map to explain trade with Europe in Roman times. For a recent synthesis and interpretation of cultural exchange, see Hansen 2012.

[9] *Pliny*, 6.20. For an interpretation of silk reeling, see 11.26.

century AD.[10] As a text that describes merchant voyages between Roman Egypt, eastern Africa, southern Arabia, and India, this work documents imports of Chinese silk floss, yarn and woven cloth.[11] Exports from Roman Egypt included various types of garments, purple cloth, and weaves with special effects (*polymita*).

multi-coloured cloths.[12] The significance of this text is that it suggests that a silk weaving industry was established in the Mediterranean region by the mid-first century.

Judging by the frequency of mention and the context of use, silk was a familiar luxury good in the Roman world by the third century.[13] Rulers seem to have viewed the material ambiguously. In the *Historia Augusta*, silk was portrayed as extravagant and effeminate, a view ascribed to Roman Emperor Alexander Severus (222-235) following decadent use attributed to Elegalalus (218-222).[14] Integration of silk into imperial regalia apparently occurred by the Council of Nikaia in 325. Eusebius related that Emperor Constantine I (324-337) appeared in a purple silk robe like 'some heavenly angel of God, his bright mantle shedding lustre like beams of light'.[15]

In early Byzantium, imperial efforts to make silk an imperial prerogative were linked with the colour purple.[16] In the ancient Mediterranean world, colourfast dyes were obtained from shellfish of the *Muricidae* family.[17] The purple-red and purple-blue colours were known

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[10] Periplus.
[11] *Periplus*, 39; 49; 56. For a definition of silk floss and its significance, see chapter 4.2. For a new interpretation of the *Periplus* text and rejection of its use as a 'handbook', see Darley 2013, 58-128.
[12] *Periplus*, 6; 7; 8; 24; 28; 39; 49; 56. For definition and discussion of πολύμιτα with the meaning of multi-coloured cloth, see *Periplus*, Comm. B, 259, 39:13.8.
[13] Young 2001, 14-16.
[14] *Scrip Hist Aug*, 40.1-2, 26.1-4.
[15] *Eusebius*, 125.
[16] Reinhold 1970, 65-66; Steigerwald 1990.
[17] Koren 2005, 136.

by various names including Tyrian purple. Murex dyes were expensive to produce and became a symbol of wealth and luxury.[18] While a detailed discussion of the colour's imperial associations is beyond the scope of this work, a brief summary is helpful to describe the relationship between silk and purple in the regulations presented below and to demonstrate development of terminology.

In early Byzantium, prohibitions restricting the use of silk and murex dyes were effected through manufacturing controls and sumptuary laws.[19] As early as 333, laws banning fraudulent use of dye materials at imperial textile factories were implemented.[20] A series of manufacturing prohibitions followed during the next two centuries, suggesting widespread non-compliance despite the state's on-going efforts to confine use of murex dyes and silk to the state.

Measures to control workers to prevent employment at private firms included an ordinance issued in 365 prohibiting textile workers from marrying outside of their guilds.[21] Similar laws were enacted in 372 and again in 380, making the concealment of imperial textile workers by private producers subject to high fines.[22] The apparent intent of a law issued in 427 was to reinforce hereditary occupational bonds in order to maintain a population of skilled dyers and weavers.[23]

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[18] Reinhold 1970, 48-70.
[19] For a recent analysis of Roman and early Byzantine legislation concerning regulation of purple, see Napoli 2004.
[20] *Cod Theod*, 1.32.1; *Cod Iust*, 11.8.2.
[21] *Cod Theod*, 10.20.3; *Cod Iust*, 11.8.3.
[22] *Cod Theod*, 10.20.7; *Cod Iust*, 11.8.5 (372) and *Cod Theod*, 10.20.9; *Cod Iust*, 11.8.6 (380).
[23] *Cod Theod*, 10.20.17; *Cod Iust*, 11.8.15.

To restrict manufacturing of silk goods to imperial workshops, private production of silk garments for both men and women was banned in 369.[24] A similar law was issued in 424 prohibiting the private manufacture of silk cloaks or dyeing with purple.[25] In 385 ships used to gather murex shells were reserved for exclusive state use.[26] An ordinance dated to 406 required private producers and households to surrender raw silk as well as silk already dyed purple.[27]

In addition to worker restrictions and manufacturing prohibitions, the right to purchase silk was confined to the state between 384 and 392.[28] In 408/9 trade with the Persians was restricted to three border cities: Nisibis, Callinicum, and Artaxata.[29] Transactions were prohibited elsewhere and required payment of duties.

Complementary to prohibitions pertaining to the production of silk goods, sumptuary laws progressively limited the use of silk textiles. In 369 non-imperial men were forbidden to wear gold or silk.[30] In 382 both men and women were banned from wearing gold-embroidered silk, cloth dyed with imperial purple, or any imitation.[31] Such goods were subject to confiscation from private homes.

In 438 the *Codex Theodosianus* was published, consolidating laws beginning with Constantine I. Between 529 and 534 the *Codex Justinianus* was compiled, substantially incorporating provisions from the earlier work. Laws governing the manufacture and dyeing

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[24] *Cod Theod*, 10.21.1; *Cod Iust*, 11.9.1.
[25] *Cod Theod*, 10.21.3; *Cod Iust*, 11.9.4.
[26] *Cod Theod*, 10.20.12; *Cod Iust*, 11.8.9.
[27] *Cod Theod*, 10.20.13; *Cod Iust*, 11.8.10.
[28] *Cod Iust*, 4.40.2. According to Lopez 1945, 9-10 this law was a restatement of an earlier law, issued between 384 and 392.
[29] *Cod Iust*, 4.63.4. Also, see La Vaissière 2005, 230 n. 10.
[30] *Cod Theod*, 10.21.1; *Cod Iust*, 11.9.1.
[31] *Cod Theod*, 10.21.2; *Cod Iust*, 4.40.1, 10.8.4, 11.9.3.

of silk in state workshops were unchanged. However, sumptuary laws relaxed certain provisions, allowing non-imperial women to wear whole silk and material woven with gold.[32]

Despite frequent wars with Persia, Byzantium's supply of silk was not disrupted significantly until the mid-sixth century.[33] In 540, Persian forces invaded Syria and sacked Antioch. Prokopios reported that to reduce the demand for silk and stem the drain of gold to Persia, Justinian I (527-565) set an artificially low price of eight gold coins for a pound of silk.[34] The ambiguity of this passage has led scholars to interpret imperial intentions in various ways. Lopez suggested that the rule set a ceiling price for the purchase of silk from foreign merchants.[35] Alternatively, Oikonomides reasoned that the provision pertained to producers and sellers of finished goods who were driven out of business by the law.[36] This second explanation is consistent with Prokopios' subsequent report that workers from the failed private silk industry were starving or emigrated to Persia.[37] Those who stayed in Byzantium were compelled to work at state factories.

Until the sixth century, Byzantium seemed to have taken a passive role in supplying itself with silk, buying goods as available from traders at border locations. After defeating the Parthians, Sasanian Persia controlled all major land-based trade routes to the west. In the early sixth century, Turkic invasions disrupted caravan routes in Central Asia, forcing Persia to acquire Chinese silk by sea in Ceylon.[38] In 519, rulers in Southern China granted Persia exclusive silk trading rights in Ceylon.[39] Moreover, Sasanian Persia effectively controlled the

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[32] *Cod Iust*, 11.9.
[33] Lopez 1945, 11.
[34] *Prok, Anecdota,* Dewing, VI.25.16-17.
[35] Lopez 1945, 11; Muthesius 2002, 151.
[36] Oikonomides 1986, 34 n. 4.
[37] *Prok, Anecdota,* Dewing, VI.25.25-26.
[38] Smith 1954, 427; Daryaee 2003, 8-9.
[39] Whitehouse and Williamson 1973, 45-46.

sea trade between Indian ports through the Red Sea to the Gulf of Aqaba, barring Byzantine merchants from trade.[40] Prokopios reported that Justinian's efforts to induce the Abyssinians to become intermediaries in the silk trade with Byzantium were unsuccessful.[41]

Byzantine efforts were then directed north to Lazica where the last segment of the trans-Caucasian trade route terminated at the Black Sea.[42] Following the Peace Agreement of 561, Lazica came within Byzantium's control, securing the northern trade route with Sogdiana, a major depot for Chinese silk.[43] In 568 a Sogdian embassy arrived in Constantinople with the offer of direct trade in silk.[44] Justin II (565-578) sent an embassy to Sogdiana in 569 to ratify a treaty and trade agreement with the Turkic khanate.[45] Trade in silk and other precious goods followed until diplomatic relations were broken off in 581.[46]

Two documents pertaining to silk date from the seventh century. An ordinance published as *Novellae* 38.6 between 610 and 640 restricted dye-house employment to descendants or relatives of workers.[47] A law known as the *peri metaxes* is dated between 545 and 610.[48] This law set a ceiling price of fifteen *nomismata* for one pound of raw silk purchased by *kommerkiarioi*.[49] Oikonomides suggested that as the exclusive buyers of raw

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[40] Daryaee 2003, 5-6.
[41] *Prok, Wars*, Dewing, I.20.9-12. Also, see Whitehouse and Williamson 1973, 44.
[42] For a recent analysis of Byzantine strategic interests in the Eastern Pontus, see Zuckerman 1991.
[43] Zuckerman 1991, 540-544.
[44] *Menand*, frag. 10.111-115; see La Vaissière 2005, 234-235.
[45] *Menand*, frag. 10.124-125.
[46] *Menand*, frag. 19.171-173. See La Vaissière 2005, 236-237 regarding changed relations among Sogdian Turks, Persians and Byzantine rulers.
[47] *Cod Iust*, III.38.6.
[48] *Imp Iust PP.A.*, 293.54. This law was dated to 545 by Zachariae. Lopez 1945, 13 suggested a later date for this law.
[49] Antoniadis-Bibicou 1963, 157-191.

silk, the *kommerkiarioi* had substantial buying leverage with silk traders and could negotiate prices, profiting from the difference between the agreed and mandated prices.[50]

The role of the *kommerkiarioi* is among the most debated issues in historical analyses of East Roman fiscal administration with opinions differing widely on the changing responsibilities of the office and the extent to which functions included silk.[51] Most historians agree that during the fifth and sixth centuries, the *kommerkiarioi* supervised and controlled trade between the empire and neighbouring countries. Seals from the later eighth century suggest a role in levying and collecting trade duties.[52] Published in 899, the *Kletorologion of Philotheos* documented the *kommerkiarioi* in the bureau of the *logothetes tou genikou*, which was responsible for collection of tax on transactions.[53] The difficulty is reconciling the functions of this office with sillographic evidence from ca. 640-730.

Oikonomides hypothesised that the increased number and wide distribution of seals across the empire demonstrated the role of the *kommerkiarioi* in disseminating sericulture technology throughout the empire.[54] This view has been criticised as speculative by several historians.[55] Reasons include the climatic unsuitability of much of Asia Minor for sericulture, the improbability that trade in luxury goods would have flourished in crisis conditions, and evidence suggesting more diversified responsibilities for the *kommerkiarioi*.

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[50] Oikonomides 1986, 35 n. 11.
[51] For a recent summary and analysis of changing roles and responsibilities, see Brubaker and Haldon 2011, 682-705.
[52] Brubaker and Haldon 2011, 699.
[53] *Listes*, 113.33.
[54] Oikonomides 1986, 42-44.
[55] Haldon 1990, 235-238; Jacoby 1991-1992, 454 n. 7; Brandes 2002, 395 ff.

Haldon put forward a convincing explanation that the dated seals of the *kommerkiarioi* and *apothekai* (storehouses) had a role in supplying the military and Constantinople.[56] Seal evidence for these offices has been shown to follow specific military events, suggesting that the office was an institutional adaption to the dramatically altered circumstances of the empire during the time.[57] While this interpretation does not exclude handling of valuables such as silk, it explains the collection, movement, and redistribution of vital commodities in service to imperial priorities.

Two sources report the arrival of sericulture technology in Byzantium. According to Prokopios, silk moth eggs were smuggled into the empire by two monks in 553/4.[58] In an audience with Emperor Justinian, the monks described the origin of the material as 'out beyond India', but then contradictorily as 'Serinda'. Having learned silk production methods, the monks explained the process of rearing silk. Since transporting live worms was impossible, the monks later returned to the empire with silkworm eggs, enabling the Romans to produce silk in their own land.

During the second half of the sixth century, Theophanes of Byzantium recorded a similar story known to us through Photios.[59] According to Theophanes, a Persian man brought the eggs to Constantinople 'from the land of Serer'. These hatched in the spring and fed on mulberry leaves and spun their cocoons. Discrepancies between the two accounts involve the source of the silkworm eggs and the identity of the persons conveying the technology to the empire.[60]

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[56] Brubaker and Haldon 2011, 682-705.
[57] Brubaker and Haldon 2011, 685-686.
[58] *Prok, Wars*, Dewing, 8.17.1-8.
[59] *Theo Byz*, 270-271.
[60] For discussion of discrepancies, see Hennig 1933.

As noted by Jacoby, these accounts of the method by which Byzantium came to possess silk rearing technology are simplistic and probably apocryphal.[61] While silk cultivation most likely developed gradually in the empire, we have no specific documentary evidence of sericulture until the eleventh century. Some historians have suggested earlier cultivation of silk fibre at various locations including Syria and the Peloponnese. The argument for Syrian silk cultivation is based on Prokopios' report that silk garments had long been made in Berytos and Tyre.[62] Muthesius suggested that Syria supplied raw silk to Byzantium based on a tentative place name identification in a Chinese text dated before 429.[63] Evidence for the transfer of moriculture and sericulture from Syria to al-Andalus after 726 is also indirect and is based on a thirteenth-century reference to Syrian mulberry trees.[64]

The notion that the *Vita Basilii* contains evidence of ninth-century sericulture in the Peloponnese is an extrapolation from the text.[65] According to the account, Emperor Basil I (867-886) received exceptionally rich gifts from the widow Danielis (ca. 820-890).[66] These included one hundred female weavers as well as an array of fine silk and linen textiles. Among the resources on her estate, the widow apparently owned a weaving establishment because she had a fine wool carpet manufactured for the Nea Church in Constantinople

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[61] Jacoby 2004, 198. For a thorough examination of fragmentary evidence that has been offered by various authors to suggest sericulture in Western Byzantium prior to the eleventh century, see Jacoby 1991-1992, 453-456.

[62] *Prok, Anecdota,* Dewing, VI.25.14-15.

[63] Muthesius 1995c, 318-320, 328. Muthesius also speculated that documented silk production in Bithynia during the Ottoman period supports backward attribution to the middle Byzantine period because the region demonstrated aptitude for silkworm rearing and manufacture.

[64] Jacoby 2004, 199 n. 7.

[65] For example, see Laiou and Morrisson 2007, 67. For discussion of Danielis' social position, see Runciman 1940.

[66] *V. Basilii*, 74.20-37.

according to her specifications.[67] However, there is no evidence for silk processing or weaving in association with Danielis' estate.

In his study of silk production in the Peloponnese, Bon observed that silk production probably took place before 1204, but documentary evidence only appeared in the thirteenth and fourteen centuries.[68] As noted by Dunn, interpretation of silk as the basis for Boetia's prosperity is an extrapolation from literary sources.[69] Guillou published important evidence regarding sericulture in Calabria based on an inventory dated about 1050.[70] Taxes there were based on the number of bags of leaves borne by mature cultivated mulberry trees. Silkworm larvae eat prodigiously, but will only feed on fresh mulberry leaves. With about 20,000 fully grown trees, the inventory shows that Calabria had the resources to sustain a substantial sericulture industry.[71]

Mulberry trees appeared occasionally in Western Byzantine fiscal surveys.[72] Without supporting data, mention of mulberry trees should not be taken as evidence of silk production, because the trees were also cultivated for their fruit. A charter issued in 1163 shows that the Bishop of Stagoi in Thessaly owned eighty-five mulberry trees.[73] Jacoby's analysis of fourteenth-century surveys and reports show moriculture at a commercial scale which suggests that widespread silk cultivation was well-established in the Frankish Peloponnese, and by extension, to Byzantine Morea and Venetian Messenia.[74]

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[67] *V. Basilii*, 76.1-11.
[68] Bon 1951, 128-129.
[69] Dunn 2006, 57, 68 n. 125, 70 n. 142. For silk in the economy of Boetia, see Savvidis 1987-1988, 40.
[70] Guillou 1974.
[71] Guillou 1974, 95.
[72] Jacoby 1991-1992, 471 n. 103.
[73] *Stagi, Astruc*, 214, 19-20.
[74] Jacoby 1994b, 41-61.

Considering the information presented above, issuance and repetition of both manufacturing and sumptuary prohibitions demonstrated the state's interest in restricting silk and purple for imperial use alone. Strong demand for silk and subsequent development of sericulture in the western provinces of the Byzantine world indicate that silk probably was produced in the empire during the middle Byzantine period. Unfortunately, no surviving evidence permits location of the empire's raw silk supply. What early Byzantine sources do show is that trade in raw silk was active and on-going, suggesting that silk textile production was sustainable on the basis of fibre imports. The topic of silk fibre production is considered on a regional basis in Chapter 4.

2.2 Imperial Roles of Silk

While production information is limited, ninth- and tenth-century sources including *taktika,* protocolary compilations, and historical accounts provide extensive details about silk in a variety of imperial contexts. To assess the importance of silk as a state resource, it is helpful to analyse the material from a functional perspective. The first topic for consideration is the ceremonial use of silk and its symbolic importance. Next, valuable silk textiles were an important component in diplomatic exchanges of various types. Lastly, silk played an economic role in the middle Byzantine state, although the full extent of this function is unclear from surviving evidence. These roles were not mutually exclusive, and collectively served to support the power of the empire.

a. The ceremonial role of silk

Analysis of the ceremonial role of silk is aided by definition of the imperial concept in the middle Byzantine period. In both an idealised sense and in reality, the state was an autocracy, with the absolute power of the monarch invested from a divine source.[75] Ceremonial practices gave form to the imperial concept. The preface to volume I of the *BOC*, attributed to Constantine VII Porphyrogennetos, reads: ‘through praiseworthy ceremonial the imperial rule appears more beautiful and acquires more nobility and so is a cause of wonder to both foreigners and our own people’.[76]

In the context of ceremony, silk performed a number of distinct functions. As an exemplar of imperial splendour, silk was among the materials employed to elevate the emperor as God’s representative on earth.[77] Use of valuable textiles for imperial vestiture projected power and prestige. Silk provided a means to convey status and position through a defined hierarchy of dress. In imperial processionals, costumes were a highly visible form of communication and display. Literature devoted to interpretation of imperial triumph and court ritual include analyses by Treitinger, McCormick, Cameron, and Berger.[78] Art historical studies of the iconography of imperial triumph offer a complementary perspective as demonstrated in essays by Ebersolt and Grabar.[79]

In a commentary on *In laudem Iustini Augusti minoris* Cameron discussed the poem as testimony to developed ceremonial ritual in the sixth century.[80] Twelve chapters of the *BOC* are attributed to Peter Patrikios (ca. 548-565).[81] Although the majority of chapters were written or heavily revised in the ninth and tenth centuries, several date from the seventh and

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[75] Laiou 1987, 382.
[76] *BOC,* Reiske, I: Preface, 3-4; tr. from *BOC*, Moffatt, 3-4.
[77] Kazhdan and Constable 1982, 34.
[78] Treitinger 1956; McCormick 1985; McCormick 1990; Cameron 1987; Berger 2001.
[79] Ebersolt 1923; Grabar 1971.
[80] Corippus, 13.
[81] *BOC,* Reiske, I: 84-95; II: 51. For a recent summary of dates attributed to various chapters, see McCormick 2012.

eighth centuries.[82] Considered collectively, the compilation provides perspectives on both the continuity of ceremonial practices and adaptations according to changing needs over time.

Considering the role of textiles in the imperial investiture ceremony, chapter 38 conveys the sanctity manifest in two items of imperial insignia: the silk chlamys and the crown.[83] During the ceremony, the patriarch prayed over the insignia which were placed on a portable altar. Next, the *koubikoularioi* draped the chlamys around the emperor's shoulders and the patriarch placed the crown upon his head. Witnesses then proclaimed the new ruler with formalised acclamations.

Court ceremonial garments were not the personal property of officials, but were kept in the palace and elsewhere for use in public events.[84] Similarly, heirloom garments for the emperor were passed down to successive rulers. In some instances, symbolic meaning in garments was portrayed as the emperor's covenant with God. In *De Administrando Imperio*, Constantine VII Porphyrogennetos evoked sacred historical tradition when he claimed that the robes and diadems of state were not fashioned by men, but were sent from God to Constantine the Great by the hands of angels.[85] The sanctity associated with imperial vesture communicated itself to the legitimate wearer, but endangered anyone with illegitimate intentions.[86]

Although some items of imperial insignia had religious associations, the chlamys was also worn in public secular settings including festivals and chariot races. Protocol required the emperor to wear the chlamys and crown when presiding at all promotions of rank above

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[82] *BOC,* Reiske, I: 41; 43-44; 46-52; 54-58; 68; 70; II: 27-30; 54. See McCormick 2012.
[83] *BOC,* Reiske, I: 38, 196-199.
[84] For special sets of clothing, see *Imp Exp*, 280 n. (C) 762.
[85] *De Adm Imp*, I.66.28-29, 32-35.
[86] *De Adm Imp*, I.64.13.26.

patrician.[87] The symbolism invested in the imperial chlamys was demonstrated by its prescribed use. At public events, the emperor used the chlamys folded over his hand to make a sign of the cross three times over the people.[88]

Much of the extensive wardrobe described in the *BOC* did not represent insignia exclusive to the emperor. Rather, the emperor occupied the apex of a dress hierarchy, with court attire (*allaximata*) defined by rank. While members of the imperial retinue wore items in common with the ruler, the emperor's dress always included garments that emphasised his superior status. As compared with senior attendants, the emperor's garments were enhanced by a deeper hue, wrought with gold, or decorated with distinctive patterns. For example, on the feast of birth of the Holy Theotokos, the emperor wore a purple *divetesion* and chlamys, then changed into a purple *skaramagion* worked with gold.[89] Even when the protocol called for a monochrome colour scheme, the emperor wore vestments that were visibly richer and finer than his attendants. On the Tuesday of Renewal week, the emperor wore a white monochrome patterned *divetesion* and *tzitzakion* while the *archons* were attired in unembellished white chlamyses.[90]

The splendid dress hierarchy provided a material representation of the essential concepts of middle Byzantine cosmology: harmony and order. The preface to the *BOC* described the purpose of the ceremonial guide:

> Through this the imperial power will have measure and order, reflecting the harmony and movement of the creator in relation to the whole, and it will appear

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[87] *BOC,* Reiske, I: 43-49.
[88] *BOC,* Reiske, I: 64, 287, 2; 64, 291, 3; 66, 299, 3; 68, 306, 23; 68, 309, 9; 70, 347, 3.
[89] *BOC,* Reiske, I: 37, 189-190.
[90] *BOC,* Reiske, I: 11, 86.

> to those subject to it to be more dignified and for this reason both sweeter and more wonderful.[91]

In the middle Byzantine period, imperial ceremonies were spectacular events. As described in the *BOC,* court costumes added to the effect of pageantry, which was heightened by the use of silk as hangings and decorations. The text also includes descriptions of silk in recurring imperial ceremonies at daily, weekly, and monthly intervals and according to the religious calendar.[92] Because ordinary and habitual practices were not customarily recorded, other evidence comes from official records pertaining to ad-hoc ceremonies, especially imperial triumphs.[93] Supplementary information comes from accounts written by foreign observers such as Hārūn ibn-Yaḥyā (ca. 900) who, as a prisoner, was an involuntary witness to court ceremony.[94]

Looking beyond the descriptive aspects of silk in ceremonial use, McCormick shaped his analysis of imperial ceremony in terms of the emperor's public image and political circumstances. Imperial ceremonials were staged events, modified and calibrated to serve considered needs.[95] Accordingly, ceremonies can be divided and analysed in terms of symbolic gestures.[96] Silk was an essential part of the ceremonial vocabulary and was applied according to the intent of the gesture. As a visible and malleable resource, the use of silk changed according to purpose. Within a wide range of potential applications, silk could serve as the focal point in ritual, or provide a backdrop for a processional setting.

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[91] *BOC,* Reiske, I: Preface, 5; tr. from *BOC*, Moffatt, 5.
[92] McCormick 1985, 189-190.
[93] McCormick 1990, 9.
[94] *Ibn Rusta*, Wiet, 134-139; see Izeddin 1941-1946 (1947); Ducène 2005.
[95] *BOC,* Reiske, II: Preface, 516.1-3. See McCormick 1990, 5.
[96] McCormick 1985, 18.

The palace official assigned to choreograph and sequence the processional was the *praipositos.* Frequent costume changes occurred at specific points along the processional route. The idea was to refresh the image of the emperor, in order to maintain the impression of imperial mystique, and to signal a change in the sequence of ritual events.[97] From the perspective of the audience, garment type, colour, and decoration identified the emperor as the central figure in the performance, which aided visual interpretation.[98]

Silk also served as a ceremonial backdrop, adding to the impression of a staged event. Theophanes Confessor described the arrival of Eirene in Constantinople in 769 before her marriage to the future Leo IV (775-780). She was escorted by many *dromones* and *chelandia* decorated with silken cloths.[99] For certain ceremonies, the city eparch was responsible for cleaning the streets and assembling decorations.[100] The *Imperial Expeditions* treatise described an ethereal image of the decorated city.[101] The route from the Golden Gate to the Chalke of the Imperial Palace was adorned with garlands, *skaramangia*, silk hangings, and candelabra, like a bridal canopy.[102]

In additional to its use in ceremonies, silk goods also provided a means of communication. Soldiers carried gold-embroidered silk banners to convey specific information to the audience.[103] The *BOC* describes the symbolic display of items of clothing or weaponry as the usual way of signalling a particular type of event.[104] When the emperor was about to go on an imperial military expedition, he ordered that a breastplate, sword, and

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97 McCormick 1985, 18.
98 McCormick 1985, 19.
99 *Theoph,* de Boor, 444, 17-18.
100 *BOC,* Reiske, II: 15, 572-573; *Imp Exp*, C.736-738; C.795-799.
101 *Imp Exp*, C.739-40.
102 *Imp Exp*, C.833; *Leo Diac,* Hase, IX.158.
103 *BOC,* Reiske, II: 15, 576-577.
104 *BOC,* Reiske, II: 24, 623, 625.

shield be hung on the gates outside of the Chalke, so that the city would know his intentions.[105]

Lastly, silk was among the many instruments used for imperial propaganda purposes. Different ceremonies were constructed according to the audience and intended message.[106] One of the most impressive events related in the *BOC* was the reception of the embassy from Tarsus.[107] This account described the emperor seated on the Throne of Solomon, accompanied by roaring mechanical beasts. The opulent silk garments of the imperial entourage and the sumptuous hangings in the reception hall delivered an unambiguous message of imperial splendour and power.

b. The diplomatic role of silk

Several historians have considered the role of silk in terms of Byzantine diplomacy. Lopez regarded the possession of silk to be a key strategic material, while Muthesius described 'silken diplomacy' as embedded in the heart of Byzantine politics.[108] Oikonomides stressed that silk textiles should be evaluated in cost-benefit terms in diplomatic interactions.[109] Grabar discussed the 'culture of shared objects' as a form of imperial court-to-court dialogue that appealed to a recipient's vanity and refinement.[110] Cormack proposed that items in the category of manufactured artistic goods, such as enamels, rock crystal, and valuable silk textiles were useful in diplomatic exchanges precisely because they could not be valued in any explicit or easily comparable way.[111] Brubaker examined textiles in cultural

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[105] *Imp Exp*, C.55-56: λωρίκιον καὶ σπαθίον καὶ σκουτάριον.
[106] McCormick 1985, 19.
[107] *BOC,* Reiske, II: 15.
[108] Lopez 1945, 1; Muthesius 1995e, 248.
[109] Oikonomides 2002, 1015.
[110] Grabar 1997, 125-126.
[111] Cormack 1995, 228; also, see Cutler 2001.

exchange in terms of both the response to the article itself and its impact on local production.[112] Collectively, these perspectives convey the various ways that silk was employed in international discourse.

The middle Byzantine notion of diplomacy provides insights to the role of silk in foreign relations. Smythe described diplomacy as the process by which relations with other powers are managed through negotiation and exchange.[113] Kazhdan discussed middle Byzantine external relations as being rooted in the notion of *oikoumene*, referring to the universal empire comprising one god and one emperor.[114] In the Byzantine worldview, the empire occupied the supreme position in the hierarchy of subordinate states in the civilised world.[115] Between the eighth and eleventh centuries, Byzantium put this concept into practice by buffering itself from other major powers with a chain of satellite states.[116] Each federated state had its own ruler and received privileges, but was considered subordinate to the emperor.[117]

Relations with subordinate states took various forms. Wars with clients were regarded as necessary to quell 'internal' rebellions.[118] Ideally, harmonious relations could be maintained peaceably by sending out embassies, giving gifts, and holding grand receptions. From a diplomatic perspective, visible displays of wealth and power were calibrated to convey the futility of attempts at competition with Byzantium as the superior state. Silk and

[112] Brubaker 2004.
[113] Smythe 1995, 305.
[114] Kazhdan 1995, 10-11.
[115] Kazhdan 1995, 13.
[116] Kazhdan 1995, 13.
[117] Shepard 1995, 53.
[118] Kazhdan 1995, 15.

other items of value were part of the standard set of favours extended to compliant rulers in the name of imperial diplomacy.[119]

Requests from subordinate states did not always conform to Byzantine expectations for gift protocol. In *De Administrando Imperio*, Constantine VII warned his son that the tribes of the north are 'desirous to acquire great profits in exchange for small service'.[120] Expanding on this point, Constantine said that such nations require and demand that some of the imperial vesture or diadems or state robes should be sent to them in return for some service or office performed by them.[121] In such instances, he advised that the 'northerners' be told that such items are to be worn only by the emperor, but then returned as property of the church.[122]

In practice, the conduct of diplomacy in the middle Byzantine period could not rely exclusively on status and treasure to achieve its ends. Byzantium's response to various international circumstances demonstrated pragmatism over ideology in the use of diplomatic resources. Silk and other valuables were used in ways unrelated to Byzantium's idealised self-conception. The *BOC* describes a tenth-century payment to an Italian noble to suppress an anti-Byzantine rising with his own forces. In return for delivering the territory into the hands of the *strategos* of Longobardia, the noble received 7,200 *nomismata* plus some silk cloth and valuable plate for himself, and more for his bishops and feudal lords.[123]

The use of silk goods for political payments and ransoms appears to have become a well-established strategy over time. Nikephoros reported that in 768, Constantine V (741-775) sent silk garments to the Slavs to ransom 2,500 captives taken from the Greek Islands of

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[119] Shepard 1995, 69-70.
[120] *De Adm Imp*, I.66.18-19.
[121] *De Adm Imp*, I.66.26-27.
[122] *De Adm Imp*, I.66.46-48.
[123] *BOC,* Reiske, II: 44, 661-662.

Imbros, Tenedos, and Samothrace.[124] In some instances, diplomatic 'gifts' were a euphemism for tribute payments. Constantine IX Monomachos (1042-1055) sent a gift to the Fatimid Caliph al-Mustanṣir on the occasion of a treaty renewing a ten-year armistice. This gift was recorded in the *Book of Gifts and Rarities* as comprising 150 beautiful mules and horses carrying 150 boxes containing hundreds of finely wrought silks and valuable textiles.[125]

The strategic value of gifts was related by Michael Psellos in his barbed description of Emperor Constantine X's (1059-1067) conduct of foreign policy. According to Psellos, the emperor required international differences to be settled, not by recourse to arms, but by sending gifts and other tokens of friendship.[126] The author gave two reasons for this policy: to avoid spending a greater part of imperial revenue on the army, and so as to not disturb Constantine's own manner of life.[127] Byzantine gift-giving practices continued in the twelfth century. As described by Niketas Choniates, Emperor Manuel I Komnenos (1143–1180) wished to astound the Seljuk sultan Kılıc Arslan II of Ikonion (1155-1192) with immense treasures including gold and silver coins, linens of the finest weaves, and luxuriant raiment.[128] The same author described negotiations between Emperor Alexios III Angelos (1195-1203) and Emir Muhyi al-Din about 1195 for a share of the annual silk consignment from Thebes.[129]

In order to explain gift exchange in the middle Byzantine period for non-economic purposes, Laiou suggested application of the theory of competitive gift exchange proposed by anthropologist Marcel Mauss.[130] This approach stressed the social nature of gifts in which an

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[124] *Nikeph*, 86.12-13.
[125] *Gifts*, 108-109.82; for a discussion of the reliability of this source, see chapter 3.1, esp. fn. 12.
[126] *Psellos,* Sewter, 259.
[127] *Psellos,* Sewter, 259.
[128] *Nik Chon,* Magoulias, 119.
[129] *Nik Chon,* Magoulias, 461; see Jacoby 1991-1992, 467, n. 77.
[130] Mauss and Halls 1990.

obligation to give and receive follows specific and mutually understood norms.[131] With some qualifications, Laiou applied this explanatory framework to exchanges between Byzantine emperors and Muslim rulers. The main problem with this approach is that unlike modern anthropological studies, evidence for social obligation in the middle Byzantine period is confined to textual sources, which at best provide limited information on motivations behind diplomatic gift practices.

Current scholarship has turned away from the idea of a generalised theory of gift-giving in favour of an approach that recognises the complexity of such exchanges.[132] The recently published *Languages of Gift* volume provides a cross-disciplinary guide for analysis. Interpretation of attested gift-giving requires critical assessment of respective motivations as well as social relationships and cultural representations.[133]

In light of current thinking about gift-giving, valuable textiles were well-suited to diplomatic exchange. From a practical standpoint, they were compact, lightweight, and durable for transport, but appeared substantial and impressive when displayed. Luxury textiles were perceived to be valuable, but were not immediately convertible into coin. By nature, the material was endlessly versatile and provided rich media for projection of messages. In this sense, valuable textile gifts were an extension of the 'experiential' displays put on for embassies and foreign visitors to the Magnaura.[134] The advantage of diplomacy through textiles is that gifts could be calibrated in terms of both the sender's interests and the recipient's anticipated response. Although there were no guarantees that transmitted messages

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[131] Laiou 2002b, 684.
[132] Davies and Fouracre 2010.
[133] Davies and Fouracre 2010, esp. 238-261.
[134] *BOC,* Reiske, II: 15.

would be received as intended, choice of motif, colour, and applied embellishment provided a means to channel discourse.

c. The economic role of silk

While the ceremonial and diplomatic uses of silk are readily apparent in our sources, definition of the material's role in the state economy presents additional challenges. Investigation requires consideration of silk within the framework of middle Byzantine fiscal and monetary policies. From an imperial standpoint, silk performed at least three functions in the economy. As a monetary instrument, it served as a 'near-substitute' or 'quasi' form of money.[135] Silk also provided a store of value for public and private wealth. In addition, customs duties on commercial silk transactions provided a source of revenue to the state.

Several historians have presented analyses relevant to an examination of the role of silk in the middle Byzantine economy. Hendy's research on the Byzantium monetary system synthesised a wide range of primary sources referring to silk.[136] Laiou discussed silk from several perspectives in her contributions to the *Economic History of Byzantium*, including trade and economic forms of exchange.[137] Oikonomides included silk in his discussion of the role of the Byzantine state in the economy.[138] Some of Jacoby's most important contributions to the field explore various aspects of the economy associated with silk.[139] McCormick sought to integrate Byzantine silk in his study of the early medieval European economy.[140]

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[135] The concept of 'near' or 'quasi' money has a specific meaning in the field of Economics. 'Near money' is an easily saleable liquid asset that performs the function of money as a store of value, but not that of a universally acceptable medium of exchange. See Pass, Lowes, et al. 1991, 374-375.
[136] Hendy 1985; Hendy 1989.
[137] Laiou 2002e; Laiou 2002b.
[138] Oikonomides 2002.
[139] Jacoby 2004; Jacoby 1991-1992.
[140] McCormick 2001, 719-728.

The economic literature relevant to an investigation of silk is extensive. In a recent volume, Laiou and Morrison described how the economic history of the empire has been reconsidered in terms of agricultural production and exchange.[141] The larger economic theme examined by Brubaker and Haldon is the success of the state's administrative apparatus in exploiting limited resources from the seventh through ninth centuries in order to transform the empire in the face of major crises.[142] Despite the territorial contractions of the eleventh and twelfth centuries, Harvey demonstrated economic expansion during the period, altering the prevailing view of stagnation and decline.[143] The monetary economy of Byzantium has been extensively studied by Morrisson.[144] Together with Cheynet, Morrison developed an empirical foundation for analysis of wages and prices in Byzantium.[145] Recent archaeological finds have supported a much-needed reappraisal of trade and markets in Byzantium.[146]

To discuss the role of silk as a form of quasi-money, it is helpful to provide a brief overview of the Byzantine monetary system. From a macroeconomic perspective, agriculture provided the basis of the middle Byzantine economy. The state's principal source of income was in the form of tax on land and farmers.[147] The period when taxes were monetised is uncertain, with various dates assigned, beginning in the eighth century.[148] Accounts by Nikephoros and Theophanes described the losses suffered by farmers forced to sell their products in adverse market conditions in order to pay their taxes in coin under Constantine

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141 Laiou and Morrisson 2007, 1-7.
142 Brubaker and Haldon 2011, 453-722.
143 For example, see Harvey 1989.
144 Morrisson 2002.
145 Morrisson and Cheynet 2002.
146 Morrisson 2012.
147 Harvey 1989, 120-162; Lefort 2002.
148 Laiou 2002e, 708; Brubaker and Haldon 2011, 474.

V.[149] The extent to which the tax monetisation policy was implemented and administered remains unclear.[150] Over time, progressive monetisation provided the state with an important means of converting agricultural surplus into revenue.

During the middle Byzantine period, the empire's largest structural expense was payment of salaries, known as the *roga*, for civil administration and the military.[151] Payment of the *roga* was the state's primary method of putting cash into circulation, before being collected as taxes to maintain the monetary cycle.[152] *Rogai* were usually paid annually in gold coin and included supplementary in-kind payments, such as food, and depending upon rank, valuable silk textiles.[153] *Rogai* were normally bestowed during Easter week from the hand of the emperor.[154] In addition to explicit payments from the state, privileges comprised a second form of remuneration that did not have a direct impact on the money supply. Examples of non-monetary privileges included tax exemption and the right to collect obligations on behalf of the state.[155]

As in most pre-modern economies, gold was the determinant of value in the middle Byzantine period. Minted into coins, gold provided the principal commodity of exchange. Having lost its most important gold mining regions during the seventh century, the empire was faced with a relatively inelastic supply of gold metal.[156] Lacking a developed banking system to provide deficit financing in the event of a shortfall, the state had to rely on various

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[149] *Nikeph*, 85.14-21; *Theoph,* de Boor, 1, 443; *Theoph,* Mango, 611.
[150] Laiou 2002e, 708-709. Brubaker and Haldon 2011, 475-482.
[151] Laiou and Morrisson 2007, 53.
[152] Morrisson 2002, 951.
[153] Oikonomides 2002, 979; for an analysis of available data, see Hendy 1985, 648-654.
[154] *Skyl Cont*, 133.18–21.
[155] Oikonomides 2002, 979.
[156] Matschke 2002, 117; for research concerning exploitation of mines, see Laiou and Morrisson 2007, 29.

measures to balance receipts with expenditures.[157] One alternative was to debase the currency, a practice that occurred from the reign of Constantine VII to Michael IV (1034-1041).[158] The empire also gained private capital through the sale of life-tenured administrative posts and titles of honour.[159] Apart from drastic measures in times of emergency, the state had a limited range of alternatives to balance receipts and expenditures.[160]

The production of silk textiles in state factories provided a means to create wealth through the production of quasi-monetary goods. During the middle Byzantine period, silk was the most common form of near-money compensation. Silk is generally reported in *roga* accounts as a complement to payment in coin. Occasionally it was used as a more explicit substitute. *Skylitzes Continuatus* described how Romanos IV Diogenes (1068-1071) substituted silk for a portion of payments that were to have been made in gold.[161]

As compared with other types of state-controlled goods, silk was an ideal imperial commodity. Unlike precious metals, which were scarce and available only in finite quantities, raw silk was an agricultural commodity. Value creation occurred in the transformation of raw materials into desirable luxury goods through the addition of skilled labour resources. Precious silks had a finite life and diminished with age and use. The fact that silk was a consumable good ensured its demand as highly-valued insignia. As demonstrated in accounts of *roga* distributions, the value of silk as a monetary resource required highly visible markers of status and selective distribution to prevent its perceived value from being diminished.

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[157] Morrisson 2002, 942.
[158] Morrisson 2002, 930.
[159] Haldon 2009, 193-195; Magdalino 2009, 224-227.
[160] For textiles, see e. Metal yarns section in chapter 4 below. For a discussion of imperial measures to obtain ready cash, see Hendy 1985, 228-237.
[161] *Skyl Cont*, 668.22-23-689.1-2.

Consequently, imperial silk products were integrated into the state's hierarchical payment structure.

Other primary sources provide accounts of *roga* payments. The following description, recorded by Liutprand of Cremona on Palm Sunday 950, gives important insights into the use of valuable silk textiles as a form of compensation.

> The first of these officials is termed the *rector domus* and his *nomismata* together with four *skaramangia* were placed not on his hands but upon his shoulders. Next were the officials termed *ho domestikos ton skholon* and *ho droungarios ton ploimon*, the one of whom commands the military, the other the navy. These, because they were of an equal rank, received an equal number of *nomismata* and *skaramangia* which on account of their bulk, they were unable to carry off even upon their shoulders, but dragged off behind them with the aid of others.[162]

Similar to *rogai* were the *philotimiai* (honour payments), distributed to civil and military officials when on campaign or to reward distinguished acts. The *Imperial Expeditions* treatise referred to 'largesse to those fighting'.[163] Another passage described the award of gifts to civil and military officials at the imperial marching camp.[164] Such payments in cash and valuable textiles were given to officials before and after a campaign to encourage morale and loyalty.[165]

Acquisition of valuable textiles as booty is a prevalent theme in historical texts. According to Leo the Deacon, when Emperor Nikephoros II Phokas (963-969) reconquered Crete in 961, his forces took an enormous quantity of precious goods and captives back to Byzantium. An imperial triumph was organised and people marvelled at the booty including

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162 *Liutprand*, *Antapodosis*, 6.10; tr. from Hendy 1985, 191. Note that in this account, the word *skaramangia* is probably used in a generic sense with the meaning of cloth as described in the *Imperial Expeditions* Treatise, see chapter 2, fn. 102. For the specific meaning of *skaramangia* as a particular type of garment, see Dawson 2006.
163 *Imp Exp*, C.261-262.
164 *Imp Exp*, C.501-511.
165 *Imp Exp*, 225 n. (C) 261.

‘garments shot with gold, purple carpets and all sorts of treasures, crafted with the greatest skill’.[166] Describing the palace of the Bulgarian king at Ohrid, Skylizes reported that Emperor Basil II (976-1025) ‘found a great deal of money, crowns with pearls, vestments embroidered in gold and one hundred *kentenaria* of gold coins which he had distributed to his army as a bonus’.[167] Attaliates described how Nikephoros III Botaneiates (1078-1081) found the palace at Chrysopolis ‘plundered of its gold, silver, and precious cloths, and striped bare’.[168]After Emperor John II Komnenos (1118-1143) lifted the siege of Edessa in 1138, Choniates wrote that he carried away magnificent gifts including silk garments interwoven with gold.[169]

Additional evidence demonstrating the use of silk as quasi-money comes from the *BOE*. Chapter 4 pertaining to clothing merchants referred to the purchase of silk garments from either public officials or silk clothing merchants.[170] Garments exceeding ten *nomismata* in value were to be declared to the eparch.[171] Both Lopez and Muthesius presumed that this regulation referred to silk produced in the homes of nobility.[172] An alternative explanation is that the regulation pertained to the resale of goods received as payment or reward. Silk textiles as quasi-money were valuable, but relatively illiquid. Assuming that merchants bought and sold textiles originally given as supplementary payments, a maximum price of ten *nomismata* was placed on the value of goods that could be freely exchanged. Transactions involving more expensive textiles were to be reported to the eparch, constraining resale value.

The economic value of textiles as a store of value is amply demonstrated by the hundreds of cloth items recorded in various types of property documents including wills,

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166 *Leo Diac,* Hase, II.28.
167 *Skyl,* Thurn, XVI, 41, 359, 17.
168 *Attal,* Brunet, 33, 6, 3-6.
169 *Nik Chon,* Dieten, I, 30, 92.
170 *BOE*, Koder, 4.2.237.
171 *BOE*, Koder, 4.2.238.
172 Lopez 1945, 17; Muthesius 1995b, 266.

contracts, marriage agreements, monastic inventories, and *typika*. Such documents probably understate the incidence of luxury textiles because they were often grouped under non-descriptive headings such as moveables, stuffs, clothing, or products in kind. For example, the 1059 will of Euthathios Boilas included silks among furniture and goods transmitted to his daughters.[173] A heading in Michael Attaleiates' 1077 *typikon* listed a variety of textiles under the heading for silks.[174] In the Iveron archive, the 1090 testamentary description of Symbatios Pakourianos specifically mentioned a purple tunic and golden cloak (*kabbadion*) received as imperial gifts.[175] The testament of his wife, Kale, included other types of valuable textile goods and silks.[176]

Donations to monastic institutions demonstrate the economic value represented by silks and other precious cloths. Among the textiles described in the Patmos inventory dated September 1200 is a group of five luxury silks. These include a high quality purple silk, a red inscribed silk in *hexamiton* weave, and a bi-colour silk with a star design.[177] Wealth donated by Gregory Pakourianos to his monastery dedicated to the Theotokos Petritzonitissa included precious imperial tunics.[178] These were given to Pakourianos by the Emperor Alexios Komnenos (1081-1118) as rewards for services.[179] This inventory also mentions other similar precious silk garments given by the emperor and his brother, the *sebastokrator* Isaac.[180]

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173 *Boilas*, 90-91.
174 *Attal,* Gautier, 1296.
175 *Ivir II*, 44.11.
176 *Ivir II*, 47.178-183. She became a nun as a widow and took the name Maria.
177 *Patmos*, Astruc, 34-37.
178 *Gre Pak*, Gautier, 1723; for other valuable textiles see lines 1724-1737.
179 *Gre Pak*, Gautier, 403-404.
180 *Gre Pak*, Gautier, 414-417.

Both Lopez and Oikonomides emphasised the importance of valuable silk goods to the middle Byzantine economy through trade.[181] Yet, imperial silk products were largely confined to exchange through diplomatic activity or as payments and rewards. As a result, discussion of the value of silk goods to the Byzantine economy pertains only to textiles produced in private workshops. Unfortunately, tax records dating to the middle Byzantine period are extremely fragmentary.[182] We can only presume that artisans and merchants involved in the private silk trade were a source of tax revenue to the state. Antoniadis-Bibicou's extensive survey of customs tariffs in Byzantium demonstrated that the *kommerkion* as a sales tax appeared in the sources beginning around 800.[183] Also called *dekate*, this tax was assessed at a rate of 10% *ad valorem* on transactions within the empire as well as imports and exports.[184]

In summary, middle Byzantine sources, mainly from the ninth and tenth centuries, demonstrate the importance of silk to the imperial state. In ceremonial contexts, silk was employed to define the social hierarchy of the court and symbolise imperial authority. Silks projected the identity of the state and were necessary equipment in staging imperial ceremonies to create the effect of pageantry. By giving material form to imperial concepts, valuable textiles provided a form of currency in international discourse. As gifts, textiles were adapted to a wide variety of situations with the potential to deliver nuanced messages, flattering to both the sender and recipient. The distinctive identity of imperial silks created a valuable instrument within the social order of Byzantine society as honorific payments. Collectively, the variety and complexity of roles assigned to silk demonstrate its value to the state as a strategic resource.

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[181] Lopez 1945; Oikonomides 2002, 983-988, 1052-1053.
[182] Dagron 2002, 423.
[183] Antoniadis-Bibicou 1963, 97-155, especially the tables on 120-121 and 124-127.
[184] Antoniadis-Bibicou 1963, 97-98.

2.3 The Imperial Silk Workshop

a. Imperial silk fiscal administration

To supply the quantity and type of material necessary for imperial use, the state operated a specialised silk workshop. Evidence for the production of imperial silk cloth is scattered among a number of primary sources. The following section examines the operation of the silk workshop from three perspectives. The first topic for consideration is the fiscal administrative hierarchy associated with state factories, followed by a review of the evidence for the geographic location of the imperial silk workshop. This section concludes with a brief discussion of the social identity of imperial silk workers.

Early Byzantine fiscal administration was dominated by two sets of institutions: the praetorian prefecture, which functioned as a territorial civil institution, and the palatine *comitivae* of the *sacrae largitiones* and *res privata.*[185] The more limited evidence for later periods has resulted in diverse views of roles and responsibilities. Studies of middle Byzantine palantine administration include works by Bréhier, Dölger, Ahrweiler, Guilland, Oikonomides, Hendy, and Brandes.[186] Precise mapping of offices between early and middle Byzantine periods is difficult because functions were combined and redistributed among various *sekreta*.[187]

As a response to the political and military crises of the seventh and eighth centuries, the former administrative hierarchy was reordered to support central imperial authority.[188] The earliest surviving middle Byzantine source documenting the reconstituted authority is the *Uspenskij Taktikon*, conventionally dated to ca. 842/3. Recent analyses have demonstrated

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[185] Jones 1992, 411-62.
[186] Bréhier 1949; Dölger 1960; Ahrweiler 1960; Guilland 1971; *Listes*; Hendy 1989; Brandes 2002.
[187] Hendy 1989, 134-135.
[188] Brubaker and Haldon 2011, 792.

that the text was written during the reign of Michael I (811-813).[189] This *taktikon* catalogued chief dignitaries and officials arranged in classes in order of rank. The *Kletorologion of Philotheos* compiled in 899 during the reign of Leo VI (886-912) is the most extensive ninth- to tenth-century source for the organisation of the imperial civil service.[190]

Evidence for the administrative structure of the imperial silk workshop comes from lists of precedence, incidental mentions in literary sources, seals, and inscriptions. A schematic view of the functional administrative fiscal hierarchy for the silk workshop is presented in appendix 2.1.

The top administrative tier of the fiscal administrative body comprised five independent *sekreta*, overseen by the *sakellarios* who exercised supervisory authority over the palatine bureaux. Formerly, this official was in charge of the *sakellion*, which gradually assumed responsibility for imperial public expenses as well as income. Precedence lists indicate that sometime in the eighth century, the *sakellarios* assumed a superior role, with administration of the *sakellion* proper assumed by the *chartoularios tou sakellariou*.[191] The *sakellarios* was represented in each of the *sekreta* by a *notarios*.[192]

Defining the functions assigned to other fiscal palatine offices, the *genikon* was responsible for assessment of land and other taxes, maintaining a list of taxpayers, and collecting payments.[193] The *vestiarion* was a repository of state wealth and operated the imperial mint.[194] The *stratiotikon* oversaw military financial activities on a centralised basis.

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[189] Brubaker and Haldon 2011, 752; Živković 2007.
[190] *Listes*, 64-235.
[191] *Adm Syst*, 85-86.
[192] Adm Syst, 82.
[193] *Listes*, 313-314.
[194] Hendy 1989, 135.

Although the thematic units appear to have had fiscal, legal, and military roles, they did not have fiscal administrative responsibilities independent from the *sekreta*.

The fiscal office most relevant to this study is the *eidikon* which was responsible for imperial warehouses and factories including imperial silk. The function was headed by the *eidikos*. Scholars generally agree that this office descended from the *idike trapeze* within the *praefectura orientis*, but the specific nature of the *eidikon's* role has been debated.[195] One area of controversy involves the specific etymology of the word with its root as either *idike* in the sense of special, in contrast to *genike*, meaning general; and *eide,* referring to things in kind or goods.[196] Brandes pointed to contemporaneous use of both *idikon* and *eidikon* in documentary and sillographic sources which indicate ambivalent usage.[197]

The *Imperial Expeditions* treatise referred to the *eidikon* as performing two different roles: managing the expenses associated with imperial expeditions, and transporting and guarding valuables. Both the *sakellarios* and the *eidikos* were responsible for providing the cash to cover the expenses of the expedition.[198] Once the army disbanded, the *eidikos* was responsible for calculating the cost of the expedition.[199] The *eidikon* also transported sacks of coins taken from the imperial bedchamber for payment to those attending the emperor.[200] Between 1058 and 1079, responsibility for the payment of *rogai* seems to have been transferred from the *eidikon* to the *sakellion*.[201] The *sekreton* of the *logothetes tou eidikou* was

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[195] For example, see *Listes*, 316-317; Brandes 2002, 165-172.
[196] Hendy 1985, 629.
[197] Brandes 2002, 167-168. For a summary of conflicting evidence, see Brubaker and Haldon 2011, 668, n. 3.
[198] *Imp Exp*, C.261-266.
[199] *Imp Exp*, C.355-358.
[200] *Imp Exp*, C.286-288.
[201] Oikonomides 1976, 135-7.

still functioning in 1081 and *eidika* are mentioned in a formula of exemption in 1086.[202] Guilland suggested that during the eleventh century, the *eidikon* was replaced by the *logothesion* of the *oikeiakoi*.[203]

Among the functions subordinate to the *eidikon* were the state factories, the *ergasteria basilika*, headed by the *archontes ton ergodosion*.[204] This office supervised four types of imperial factories: *blattion* for silk weaving, *chrysoklabon* for gold embroidery, *chrysochoeion* to fabricate gold jewelry, and *armamenton* to produce arms and weapons.

Additional evidence associated with the administration of the imperial workshop is provided by the woven inscription on the Aachen ‘imperial elephant’ silk that was taken from the shrine of Charlemagne and is now housed in the Munster Treasury.[205] As shown in appendix 2.2, the inscription reads: ‘in the time of Michael, *primikerios* of the imperial bedchamber and *eidikos* when Peter was the *archon* of Zeuxippos.’ Michael, the *eidikos*, held the rank of *primikerios* in the imperial bedchamber, one of eight ranks by which palace officials were graded. The second line of text states that Peter was the *archon* (head) of Zeuxippos, which indicates oversight of an imperial function.[206] Unfortunately, the indiction number is no longer visible on the silk.

Additional primary evidence pertaining to the *archontes* of silk workshops comes from seals published by Oikonomides dated to the seventh and eighth centuries.[207] Sillographic evidence shows that imperial factory directors were also known as *ergasteriarchai* and often

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[202] *Lavra I*, 1, no. 48.50.
[203] Guilland 1971, 96.
[204] *Listes*, 123.6-10.
[205] Vial 1961; Muthesius 1997, 183.
[206] Muthesius 1995f, 65.
[207] Appendix 2.3 provides examples *archontes tou blattiou* seals published by Oikonomides. See Oikonomides 1985, 50-52.

combined their functions with those of the *kommerkiarioi*. Hendy observed that the combination most frequently seen on seals is coincidental use of *genikos kommerkiarios* and *archon tou blattiou* (appendix 2.3).[208] On this point, Haldon noted that the two departments maintained separate functions, and that association on seals signalled coordination between the administrative bodies.[209]

Below the level of the *archontes tou blattiou*, textual references to imperial factory officials and workers are limited to three citations. The *Kletorologion of Philotheos* referred to *meizoteroi ton ergodosion* meaning workshop foremen.[210] In an incidental mention, the tenth-century history of Leo the Deacon referred to a manager or supervisor of an imperial weaving establishment.[211] The vita of Antony II Kauleas, patriarch of Constantinople (893-901), also included a reference to the head of the imperial silk factory.[212]

b. Imperial workshop location

Primary evidence suggests the location of the imperial silk workshop. Between the fourth and sixth centuries, the state operated a number of weaving mills at various locations throughout the empire including wool and linen factories, dye works, and special workshops to produce high quality garments for the court. Incidental mentions of textile factories in the East include wool mills at Heraklea of Thrace, Cyzicus, Caesarea of Cappadocia, and Tyre; a linen mill at Skythopolis; and dye works in Phoenikia and Cyprus.[213] In the middle Byzantine period, the primary record is confined to citations of imperial textile workshops in Constantinople.

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[208] Hendy 1985, 630.
[209] Brubaker and Haldon 2011, 694.
[210] *Listes*, 123.10 and 317.
[211] *Leo Diac,* Hase, 146.91: βασιλικῆς ἱστουργίας ὄντι μελεδωνῷ.
[212] *V. Kauleas*, 18.25.
[213] For a summary of source references, see Jones 1992, 836.

Among the factories under state control, mints are the best documented because of surviving numismatic evidence. In the middle Byzantine period, coins were mainly produced in Constantinople. Regional mints were established when the need arose, but there is no evidence of a sustained regional network of mints on a scale similar to the earlier period.[214] The location of both coin and textile production in Constantinople suggests that both types of imperial factories were subject to the same centralising forces.

Within the imperial city, the palace complex provided the most likely site for silk production. The design and layout of the monumental complex has been studied by several scholars including Janin, Mango, and Magdalino.[215] The Imperial Palace environs, residence of the Byzantine emperors for hundreds of years, was built, enlarged, and altered over the centuries, resulting in a complex agglomeration of buildings. The walled complex was bounded by the Hippodrome, the Baths of Zeuxippos, and the Tetrastoon, with later constructions down a sloping hillside to the Marmara Sea.[216]

Several texts contain incidental mentions of imperial workshops located in or near the palace complex. On 25 December 792 Theophanes Confessor relayed that the imperial gold embroidery workshop, the *Chrysoklabarion* situated at the *Chrysion*, caught fire.[217] Although the location of the *Chrysion* is not specifically known, the *BOC* referred to the structure as being outside but near the palace complex.[218] The *Patria* noted that the *Chrysoklabon* was attached to the Imperial Palace.[219] The *Patria* also mentioned two *ergodosia* built by Eirene in about 790 near the Palace of Eleutherios, but did not specify the kind of goods produced

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[214] Hendy 1985, 146-147.
[215] Janin 1950; Mango 1959; Magdalino 2000; Magdalino 2002.
[216] Mango 1959, 12.
[217] *Theoph,* Mango, 644,
[218] *BOC,* Reiske, II: 15, 583, 4.
[219] *Patria*, 145.5.

there.[220] This palace was located in a different quarter of Constantinople, overlooking the harbour of Eleutheros on the Marmara Sea coast (appendix 2.4).

Describing a foiled plot in 971 to seize the throne, Leo the Deacon mentioned the location of the silk weaving workshops in or near the palatine complex.[221] The plotter was waiting at the home of one of his retainers in the quarter of Sphorakion when one of his followers slipped out of the house and requested help from a friend who was a supervisor in the imperial weaving factory. Presumably the friend lived in or near the Sphorakion area adjacent to the palace complex (appendix 2.4). According to Janin, the Sphorakion district was slightly to the north and west of Hagia Sophia, part way between the Milion and the Forum of Constantine.[222]

Angelidi published a foundation document for the Monastery of *Hodegoi* in Constantinople which is provisionally dated to the ninth century. The text described the donation of the Palace of Marina, which was in use at the time as a factory to manufacture imperial textiles.[223] Because the text did not specify the type of precious fabric manufactured there, the factory could have been either a gold embroidery or silk workshop. This palace was located in the southern part of the city, close to the sea (appendix 2.5). Magdalino suggested that the Palace of Marina would have been a large and solidly constructed structure, easier to re-use than to demolish.[224]

Lastly, the inscription recorded on the Imperial Elephant silk indicates that a palatine silk weaving factory was located at Zeuxippos, presumably the same location as the extensive

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[220] *Patria*, 269.13-4.
[221] *Leo Diac,* Talbot, 190-191.
[222] Janin 1950, 393.
[223] *Hodègoi*, 145.185-7.
[224] Magdalino 2000, 216-217.

bath complex (appendix 2.6). Initially constructed by Emperor Septimius Severus (193-211) around 196, the complex was destroyed by the Nika riots in 532, but was rebuilt.[225] Zeuxippos still served as a bathing place when Emperor Philippikos (711-713) used it in 713.[226] By the tenth century, the *Patria* reported that the baths were no longer functioning.[227] Accounts also mention that a portion of the structure was transformed into a prison known as the Numera.[228]

Given the large size of the baths and the Byzantine tendency to re-use large structures for other purposes, it is conceivable that part of the site served as an imperial textile workshop. Indeed, the use of bath fixtures for textile processing would have been a logical choice. British Academy excavations in 1927-1928 established a provisional site for the baths.[229] This location is supported by observations made by Mamboury in 1952 during construction in the area. Reportedly, a trench revealed two or three rounded chambers with a water conduit that may have belonged to the baths.[230]

c. Social identity of imperial silk workers

Although textual references are very limited, it is possible to assemble a partial view of imperial silk workers. According to the passage from Leo the Deacon cited above, the silk factory superintendent was asked to summon a body of workers from the weaving establishment to join the plot to seize the throne.[231] The superintendent promised to help and

[225] For the history of the baths, see Guilland 1966.
[226] Mango 1959, 30, 39.
[227] *Patria*, 168.5-9.
[228] Mango 1959, 41.
[229] Mango 1959, 37.
[230] Mango 1959, 20.
[231] According to Dagron 2002, 432, the word *systema* in this text refers to a group or body of workers rather than to the usual translation in the sense of a guild or corporation.

went off as if to summon his fellow workers.[232] From this passage, we surmise that silk workers were hierarchically organised and had enough male members to comprise a force capable of assisting with the plot. The text also implied that the workers had sufficient identity as a group to be mobilised for political action, a topic examined by Vryonis for the eleventh century.[233]

Several sources attest to the use of slaves in imperial workshops.[234] The passage describing the widow Danielis' gift of one hundred female textile slaves to Emperor Basil I was discussed above. Theodore of Stoudios (759-826) wrote about a monk named Arkadios who was condemned for icon veneration during the Second Iconoclastic period (814-842). According to a letter, the monk was forced to work as a slave in an imperial cloth workshop.[235] The *BOE* stated that the slaves of some types of private artisans who broke rules could be made into state slaves.[236] Apparently, a large enough body of imperial slaves existed to warrant the notice of Leo VI, who provided them the right to dispose of their property during their lifetime and at death.[237]

Summarising information about the imperial silk workshop, valuable textiles were the product of a sophisticated and integrated administrative apparatus geared toward effective management and control of resources. Production of imperial silks involved a high degree of planning and organisation to ensure that specified requirements and quantities were available as needed. Evidence suggests that the administrative framework for the *eidikon*, which governed the production of silks, remained in place through much of the eleventh century. To

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[232] *Leo Diac,* Talbot, 191; *Leo Diac,* Hase, 146.90-1 and 147.1-5.
[233] Vryonis 1997.
[234] See Hadjinicolaou-Marava 1950, 25, 35, 45, 47.
[235] *Theod Stoud*, 390.20.
[236] *BOE*, Koder, 12.9.
[237] *Nov Leo VI*, 150-153.

aid in planning and coordination and to control the flow of finished goods, the state silk workshop was located in or near the imperial complex. While social information about workers is fragmentary, sources suggest a professional workforce comprising free men and slaves in a hierarchical organisational structure.

2.4 Regulation of the Private Silk Industry in Constantinople

While the state controlled production of silks in the imperial workshop, it had to contend with the long-term problem of non-imperial use of silk and purple dyes. During the reign of Basil I, compilation and publication of the imperial laws known as the *Basilika* was undertaken and was completed in the first years of Leo VI's rule (886-912). Many of the laws pertaining to silk and purple dye that were carried over to the collection from the *Corpus Juris Civilis* had long been obsolete. Although the *Basilika* specifically prohibited silk production and use, especially purple items, publication of *Novellas Leonis 80* demonstrates the discrepancy between civil law and common practice. In this novel, dated between 894 and 912, Leo VI (886-912) wondered at the petty jealousy of former rulers in denying citizens the right to purple goods.[238] Noting that his subjects attached importance to such items, the emperor permitted use of purple cloth scraps.[239]

Regulation of the private silk industry in Constantinople was governed by the eparch of the city. Published in 911/12, the *BOE* comprised twenty-two chapters of regulations pertaining to various private trades in Constantinople. The principal unit of organisation in the regulations was the guild (*systema*). The guild framework has been studied by a number of

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[238] *Nov Leo VI*, 272-275.

[239] *Nov Leo VI*, 272-275. See Jacoby 1991-1992, 457 n. 22. The novel did not mention either murex dyes or silk.

scholars.[240] Mickwitz examined possible connections between Byzantine guilds and those of medieval Europe.[241] Dagron described the Byzantine guild concept as a form of legal association, performing various functions including organising trade among members, representing collective interests to authorities, and transmitting technical knowledge.[242] Schreiner cautioned that it is misleading to look at guild regulations as a measure for the economy as a whole.[243]

Analysis by Papagianni showed how the *BOE* demonstrated middle Byzantine social concepts.[244] Even though the guild remained the principal instrument for state control of important economic sectors, the composition and membership of guilds changed from earlier times. In the middle Byzantine period, guild members were the persons responsible for *ergasteria*; membership did not include either skilled workers or manual labourers. To conduct business, *ergasteriakoi* combined the help of their families with the labour of others, including apprentices, slaves, and paid workers of varying skill levels who were hired on a contractual basis. In turn, *ergasteriakoi* were dependent upon the support of their financial backers, often members of the aristocracy.[245]

Although the *BOE* established a regulatory framework, the text does not describe the state's intentions. In early studies, scholars regarded state intervention in the economy as extensive, resulting in a command economy.[246] Recent interpretations have considered a more confined regulatory framework, overseeing the activities of certain trades important to the

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[240] See Mickwitz 1936; Mendl 1961; Simon 1975; Schreiner 1989. Other sources include: Vryonis 1963 and Maniatis 2001.
[241] Mickwitz 1936.
[242] Dagron 2002, 405.
[243] Schreiner 1989, 61.
[244] Papagianni 2002.
[245] Dagron 2002, 422.
[246] For a review of the literature, see Maniatis 2001, 347.

capital.[247] Activities of interest included juridical practices and money changers, high-value products, special trades in which fraud was common, workshops receiving imperial commissions, and trades providing basic goods for the urban population.[248]

The five chapters devoted to regulation of the silk trade attest a thriving and well-established industry. Chapter 4 referred to the *vestiopratai*, the merchants of finished silk goods. Regulations pertaining to the *prandiopratai*, the designated sellers of imported silk goods, appeared in chapter 5. Chapter 6 covered the *metaxopratai*, the buyers of raw silk. The *katartarioi* discussed in chapter 7 were responsible for preparing silk for weaving. Chapter 8 applied to the s*erikarioi*, the guild responsible for silk dyeing, weaving, and tailoring.

Collective consideration of the silk chapters shows that the industry was regulated as a closed circuit with controlled points of entry and exit. In addition to providing a framework to collect taxes on transactions, provisions for each guild channelled the flow of goods to prevent unauthorised outflows. Appendix 2.7 provides a schematic view of the flow of goods by production stage and identifies control points. A main concern addressed in several chapters was control of transactions involving either foreigners or 'outsiders' both for the purchase of raw silk and the sale of finished goods.[249] Historians have debated whether 'outsider' referred to imperial subjects from outside of the city or to foreigners.[250] Chapter 8 also prohibited firms from allowing skilled silk workers to leave Constantinople.[251]

Restrictions also forbid participation in more than one guild. The rationale for prohibiting vertical integration has been discussed by various historians. Maniatis regarded

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[247] Dagron 2002, 406.
[248] Dagron 2002, 406.
[249] *BOE*, Koder, 4.1, 8.3, 8.8, 6.5: Οἱ ἀπὸ τῶν ἔξωθεν.
[250] For example, see Lopez 1945; Muthesius 1995b, 255-314; Jacoby 1991-1992; *BOE*, Koder.
[251] *BOE*, Koder, 8.7.

the measures to channel goods through the system as a means to forestall textile manufacturing outside of the guild system.[252] In a subsequent work, he suggested that the state wished to prevent concentration of market power as a means of undermining the regulatory framework.[253] Alternatively, Vryonis saw the guilds as a force for urban political activity, posing a threat to the state in the same manner as the factions.[254]

A third reason for regulation was to define goods that were specifically prohibited for all but imperial purposes (*kekolymena*).[255] The *serikarioi* were banned from use of murex dyes and manufacture of imperial types of silks and garments. Other silk industry regulations enforced fair and equitable behaviour on the part of firms within a guild. Both the *serikarioi* and the *metaxopratai* were required to employ workers for a maximum term of one month.[256] This puzzling provision can be interpreted in different ways. It may have demonstrated the state's interest in ensuring fair treatment of workers, or limited concentration of highly skilled workers in particular workshops. In either case, short-term contracts would have meant workforce instability, representing an on-going risk to silk textile producers.

Collectively, the regulations convey the state's on-going interest in maintaining silk as an imperial prerogative. The increased specificity of silk prohibitions suggests the problem of imitative production and use. The five silk chapters of the *BOE* describe an integrated network of businesses developed over time with strong demand for silk products. Since outright prohibitions had proven ineffectual, the state sought to control the industry structure, the types of products produced, and the distribution of finished products. Apart from these measures, private transactions involving silk were relatively unfettered. The regulations

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[252] Maniatis 1999, 269.
[253] Maniatis 2001, 341.
[254] Vryonis 1963, 293.
[255] *BOE*, Koder, 8.1-2, 8.4.
[256] *BOE*, Koder, 6.2, 8.12.

pertaining to the *serikarioi* are especially telling. Concerns about reproduction of imperial quality silks required specific delineation of prohibited characteristics. The meaning and implications of particular prohibitions are examined in chapter 4.

2.5 Silk in the Eleventh and Twelfth Centuries

After the mid-tenth century, the nature of source evidence pertaining to silk changes. Only the treatise attributed to Pseudo-Kodinos between 1347 and 1368 includes some protocollary information about imperial textiles.[257] Surviving sources include several histories and other literary works. Jacoby gathered evidence from several European sources attesting types of silk cloths from the island of Andros that are dated to the early twelfth century.[258] Apart from identification of the location by name, we have no additional information about the industry or types of products.[259]

The two themes that characterise the Byzantine silk history during the eleventh and twelfth centuries are explicit references to private silk workshops in the empire's western provinces and the series of trading privileges granted to Italian merchant states beginning in the late eleventh century. The most dramatic event occurred in 1147 when Roger II, king of Sicily (1130-1154), dispatched a fleet to invade Byzantine territories. Choniates relayed that Sicilian forces captured Corinth and Thebes and carried away female silk workers and fine golden cloths.[260] Otto of Freising provided a similar account and included Athens among the

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[257] Pseud Kodin.
[258] Jacoby 1991-1992, 460-461.
[259] Jacoby 1991-1992, 461.
[260] *Nik Chon,* Dieten, II.1.98.40-49.

cities captured.[261] He also reported that the motivation for kidnapping was to obtain skilled workers to teach weaving arts known only by Greeks among the Christians.[262]

Literary sources show that silk production in Thebes and Corinth recovered soon after the silk workers were abducted.[263] A letter written by John Tzetzes between 1148 and 1154 noted the skill of Theban weavers.[264] Writing in the 1160s, Benjamin of Tudela described the Jewish silk weavers in Thebes as the most skilled in silk and purple in the empire.[265] In Thessaloniki, he stated that the Jews were oppressed and lived by silk weaving.[266] Of Constantinople he wrote 'From every part of the empire of Greece tribute is brought here every year, and they fill strongholds with garments of silk, purple, and gold'.[267] He describes the city's inhabitants as 'they go clothed in garments of silk with gold embroidery'.[268] Among the Jews in the city, he said 'there are artificers in silk and many rich merchants'.[269]

Evidence for the silk industry in Western Byzantium is part of a larger economic expansion and trend toward urbanisation that took place in the region during the eleventh and twelfth centuries.[270] The trade privileges awarded by Emperor Alexios I Komnenos to Venice in the last quarter of the eleventh century had significant consequences for the empire.[271] Although not specifically associated with silk, trade concessions had a long-term impact on the silk industry. Jacoby traced the origins of Venetian commercial and maritime expansion in

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[261] *G. Frid*, p. 370, 33. For additional primary sources, see Jacoby 1991-1992, 462-463, n. 54.
[262] *G. Frid*, 33.
[263] For a summary of archaeological evidence for dye works, see Louvi-Kizi 2002.
[264] *Tzetzes*, 101-103, no. 71.
[265] *Be Tud*, 10; for dating and an improved English translation, see Jacoby 2008.
[266] *Be Tud*, 11.
[267] *Be Tud*, 13.
[268] *Be Tud*, 13.
[269] *Be Tud*, 14.
[270] For changed consumption patterns and accumulation of wealth, see Kazhdan and Epstein 1985, 74-119.
[271] *Trattati*, 35-45. The conventional date assigned to the chrysobull granting trade privileges is 1082; for a date of 1092 see Frankopan 2004.

the eleventh and twelfth centuries with respect to Byzantium and Muslim entities.[272] In the eleventh century, Venetian traders participated in internal trade within the empire with tax exemptions to the relative disadvantage of Byzantine merchants. From 1126, benefits were extended to Byzantine subjects trading with Venetians, explaining their role in transporting and trading silks in Constantinople as well as in the West.[273]

Some evidence concerning textile exchange is found in *panegyris* (festival) accounts. Vryonis studied these events, which were apparently widespread in the empire, as both a religious and commercial institution.[274] While the term itself means gathering, and the events were centred on saints and shrines, some festivals appear to have included a market. An important account appeared in the *Timarion.* This work described the *panegyris* of Saint Demetrios in Thessalonike during the early twelfth century. Surveying the arrangement of the tent-shops of the textile market, the author wrote:

> Every type, which [is in the form of] textiles and yarns for men and women, and all those that commercial ships bring to the Hellens from Boeotia, the Peloponnese, and Italy. Also Phoenicia contributes and Egypt, Spain and the Pillars of Hercules weave the most beautiful of fixtures. Merchants bring these directly from the various lands to former Macedonia and to Thessalonike. The Euxine sends its goods to Byzantium and thence it ornaments the *panegyris*, many horse and mules bearing the loads from there.[275]

Byzantium's participation in regional trade is well-documented in a wide variety of sources and in a number of different ways. Several scholars have investigated the activities of

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[272] Jacoby 2009.
[273] Jacoby 2000, 134-135, 139. Pisa and Genoa were granted more limited privileges in the twelfth century. Trade in the tenth century was implied by Luitprand of Cremona's account of his embassy to Constantinople (968). Luitprand claimed that prohibited silks were handled by Venetian and Amalfian traders. See *Luitprand*, 211-212, 55, 899-900.
[274] Vryonis 1997, 259-260.
[275] *Timarion*, 25-31, 55-59; Vryonis 1997, 256-259.

foreign merchants in Constantinople and elsewhere in the empire.[276] Chapter 6 of the *BOE* mandated that foreign merchants were required to store their silk goods and transact business at the *mitata* which also served as a guesthouse.[277] Chapter 10 of the *BOE* referred to the Black Sea port city of Trebizond as a centre for trade in dyes with Muslim merchants from the East.[278]

2.6 Summary

In tracing the history of silk in Byzantium, it becomes clear that the material was employed for a wide variety of uses. Evidence shows the gradual westward movement of the industry in terms of both production and consumption. Although silk had been a valuable luxury product for centuries, the early Byzantine state sought to confine the material as an imperial prerogative through laws restricting manufacture and use. In response to the crises of the sixth and seventh centuries, silk was among the many resources rationalised by the state to serve imperial purposes. The material was extensively integrated into the social and economic framework of the middle Byzantine court as a means to project imperial conceptions through ceremonies, diplomatic gestures, and rewards. The success of these collective measures as relayed through primary sources now defines the modern conception of Byzantine silk.

Unlike other valuable materials available only in limited quantities, silk was not easily restricted to the imperial sphere. Given the apparent failure of outright prohibitions, the state sought to regulate the private silk industry in order to control the production and circulation of certain types of silks. In contrast to the earlier period, prerogative was not defined by material or colour alone, but by a more specific set of factors defined as *kekolymena*. The production

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[276] For discussion of foreign merchants in Constantinople, see for example Lilie 1984; Jacoby 1994a; Reinert 1998; Anderson 2009; Laiou and Morrisson 2007, 138-145.
[277] *BOE*, Koder, 6.1. See Lopez 1945, 22-40; Maniatis 1999.
[278] *BOE*, Koder, 10.1-2.

factors associated with the imperial silk workshop involving materials, equipment, and specialised skills were not unique to the imperial state. Over time, reproductions of imperial silks occurred within the empire and beyond. During the middle Byzantine period, trade in silk was a regional industry comprising goods at various stage of production – from fibre through finished goods. The market was well developed, involving an extensive network of exchange.

The following chapter defines a methodology to gain a deeper understanding of silk in context using the fragmentary textile mentions that appear in Byzantine, Islamic, and Jewish contemporaneous sources. Chapter 4 applies this investigative strategy to discuss the social role of the silk industry, to define attributes in the hierarchy of valuable court textiles, and to integrate the Byzantine silk industry with regional developments.

PART I: CHAPTER 3 - TEXTILE MENTION DATABASE RESEARCH METHODOLOGY

While necessary to provide a historical framework for analysis, a generalised approach to the study of Byzantine silk forgoes much detailed evidence concerning the production and consumption of particular products. A review of middle Byzantine sources reveals a large number of textual 'mentions' describing textiles. These are typically incidental in nature with only partial descriptive information included. In most cases, sources were not intended to provide detailed accounts of textiles, and comprehensive descriptions are rare. Consequently, the fragmentary content of each mention limits the amount of data that can be gathered through conventional textual analysis.

Analysed collectively, however, these 'mentions' are very revealing and include specific details about textiles including materials, weave type, decoration, end use, quality, and usage context. This chapter examines the nature of source evidence associated with textiles and defines a methodology to organise and interpret information. The goal is to devise a methodology and framework for analysis to integrate with evidence from figured silk textile remains.

For the purposes of this study, a 'textile mention' is defined as a block of text taken from a primary source for analysis. It includes descriptive information and contains one or more textile-related attributes. A textile mention can range in length from a brief phrase to a paragraph. The defining characteristic is coherent internal reference; parsing the text into smaller units would change the interpretation of various attributes. Essentially, a textile mention is the 'smallest common denominator' of textual information relevant to this project.

Although the primary focus of this work is figured silks in Byzantium, source evidence includes relevant contemporary accounts from Islamic and Jewish sources. Textile materials and finished goods were traded extensively through various channels within the Mediterranean and Near East. For the purpose of this study, a regional approach is necessary to fully interrogate available evidence.

To define a research methodology appropriate to textile mentions, this chapter is divided into four sections. The first describes the general characteristics of the source evidence. Scholarly interest in collating and analysing details about cloth is divided mainly by culture with distinctive bodies of Islamic, Jewish, and Byzantine textile-related literature developing independently. Second, prosopography is considered as a model framework to capture and consolidate textile details. Next, relational database software provides a means to organise and evaluate information. This chapter concludes with a discussion of considerations and conventions involved in assembling a structured database of textile mentions.

3.1 Source Evidence

a. Islamic sources

Islamic texts contain abundant references to silk use for clothing and furnishings. They offer varied glimpses of textiles in the context of contemporary life, but are also problematic as a historical resource. In the first centuries after the conquest, Arab historical transmissions drew upon oral and literary traditions to produce writing in the form of narrative collections.[1] Historians have developed various methodologies to interpret historiographical information and date the material.[2] Over time, distinctive historical literary forms developed from early transmissions to classify and convey different types of written knowledge such as biographies

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[1] Noth and Conrad 1994, 2-4.
[2] Noth and Conrad 1994, 25-61.

and chronologies.[3] To varying degrees, these forms retained elements of the earlier narrative tradition, making them problematic as sources without corroborating information.

In the newly conquered lands, an emerging Arab Muslim elite adopted elements from the material cultures of the former empires.[4] Morony noted several factors contributing to the process of appropriation including vestigial elements of the former social order as well as the means and access to luxuries in the local material culture.[5] Arabic sources describe great households, retinues, dining customs, and luxury textiles.[6] An important point of differentiation from Sasanian practice is that clothing and textiles served to indicate relative wealth, but did not designate different levels or ranks within the social order.[7] Muslim distinction of dress by status, occupation, or religion emerged only later, beginning in the eighth century.[8]

Islamic literary works describing textiles include: histories, geographies, literature, poetry, and regulations. Information concerning textiles is widely scattered in the literature with varying details and descriptive conventions. Textiles in the economic life of the caliphate are known mainly from ninth and tenth-century geographers such as Ibn Rusta, al-Iṣṭakhrī, Ibn Ḥawḳal, and the author of the anonymous *Ḥudūd al-ʻālam*. Some geographers travelled widely and wrote from first-hand observation. Such works provide details about the material culture of the Islamic world not available elsewhere.[9] Geographical writing from the period

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[3] Robinson 2003, 24.
[4] Morony 1992, 282.
[5] Morony 1984, 258.
[6] Morony 1984, 258-260.
[7] Morony 1984, 260.
[8] Morony 1984, 260.
[9] Rosenthal 1968, 106-110.

also incorporated some historical information.[10] Historians who recorded textile details included Makdisi, Mas'ūdī, and Miskawayh.

The *Book of Gifts and Rarities* comes from an Arabic manuscript dating from the Ottoman period and covers the seventh to eleventh centuries for the Islamic world.[11] The text conveys extensive details about textiles and other valuable and exotic items involved in court exchanges. Recently, Christys examined the text as a historical resource. Her analysis of the purported embassy of Queen Bertha to Baghdad in 906 demonstrates some of the ways the text was altered to meet the needs and tastes of court writers in the genre of *adab*.[12] Consequently, use of the *Book of Gifts and Rarities* for historical analyses must take into the account the nature of the source.

As manuals for supervision over trades, *ḥisba* treatises contain specific information about contemporary textile products and practices. The *Mahasin al-Tidjāra* provides information about the commercial practices of merchants and describes characteristics of goods in the marketplace.[13] Reference books and dictionaries include definitions of some textile terms that would otherwise be lost.

The historiography of Islamic textiles is substantial and spans more than 150 years. In 1845, Dozy published his pioneering work, *Dictionnaire détaillé des noms des vêtements chez les Arabes*.[14] In the late nineteenth and early twentieth centuries, German orientalists such as von Kremer, Karabecek, and Mez compiled Islamic source material pertaining to textiles.[15] In

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[10] Rosenthal 1968, 106.
[11] Gifts.
[12] Christys 2010, 160-161. As a literary genre in this context, *adab* has the approximate meaning of *belles-lettres*. See Gabrieli 2013.
[13] Dimashki.
[14] Dozy 1845.
[15] Kremer 1884; Kremer 1887; Karabacek 1881; Karabacek 1883; Mez 1937.

the first half of the twentieth century, information about Persian textiles was published by Wiet and subsequently Ackerman.[16] Lamm's 1937 *Cotton in Mediaeval Textiles of the Near East* included some primary source material on various textile fibres.[17] Grohmann's article on *ṭirāz* synthesised a wide range of source material.[18]

The most comprehensive compilation of Islamic sources to date is Serjeant's *Islamic Textiles: Material for a History up to the Mongol Conquest*.[19] Serjeant drew upon histories, administrative texts, geographies, biographies, and other forms of writing, arranging the material geographically, chronologically, and topically. He compiled a glossary of related terms comprising about 1300 words, including articles of clothing, production methods, tools, and raw materials. Complementary to Serjeant's geographical compilation, Lombard's 1978 posthumous work *Les textiles dans le monde musulman du VIIe au XIIe siècle* provides an interpretative resource for the study of Islamic textiles.[20] His research integrated source evidence with discussion of fibre types, processes, usage, and workshop settings.

During the past half-century, Islamic textile studies have remained an active area of research, with several important studies based on literary evidence including unpublished dissertations. Farag's 1979 work on Byzantium's relations with its Muslim neighbours during the reign of Basil II contains a number of references to textiles in the context of diplomacy and trade.[21] Bierman's 1980 study analysed the court context of inscribed textiles and their political significance.[22] Sokoly's 2002 work examined the relationship between the

[16] Wiet 1933; Wiet 1947; Ackerman 1938-1939.
[17] Lamm 1937.
[18] Grohmann 1934.
[19] Serjeant 1972.
[20] Lombard 1978.
[21] Farag 1979.
[22] Bierman 1980.

production, administration, and use of *ṭirāz* textiles in Egypt under the Umayyad, Abbasid, and Fatimid dynasties.[23]

Based on a colloquium in 1995, the Abegg-Stiftung foundation published a volume that included several textual investigations of Islamic textiles.[24] A recent conference at Katoen Natie in Antwerp resulted in the publication of papers examining literary sources concerning furnishing textiles.[25] The inscription evidence conveyed through Islamic textiles presents extensive opportunities for research. The classic study by Kühnel and Bellinger demonstrated the value of inscriptions to textile analysis.[26] A recent volume edited by Fluck and Helmecke provides a compilation of research on Greek, Coptic, and Arabic textile inscriptions from the first millennium.[27]

b. Jewish sources

The Cairo Genizah comprises a wealth of data pertinent to this technical study of silk based on writings dated from the tenth to the thirteenth centuries. The types of evidence most relevant to textile research are trader letters, wedding trousseau lists, and responsa.[28]

Analysed collectively, trader letters provide extensive details about textile commerce and show a high degree of correspondence with Arabic literary sources. Genizah scholars have demonstrated that the Jewish community in Fustat was highly integrated into the contemporary Fatimid society and economy, allowing generalisation from Genizah evidence

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[23] Sokoly 2001.
[24] Salim, Barnes, et al. 1997.
[25] Fluck and De Moor 2009.
[26] Kühnel and Bellinger 1952
[27] Fluck and Helmecke 2006.
[28] See definition below p. 87.

for study of contemporary urban material culture.[29] Analysis of textile mentions provides valuable insights into the hierarchical use of fabrics within the sphere of private wealth.

Specific evidence concerning textiles comes from wedding trousseau lists (*ketubbā*). These documents were contractual obligations that specifically itemised a bride's property. Considered collectively these inventories are an important resource for domestic material culture studies. A groom had a fiduciary obligation to a bride's family, which meant that values were probably fairly and accurately recorded. By convention, a bride's property was organised according to certain standard categories, with textile-related items under headings for garments and household furnishings.

The Jewish diaspora in the centuries around the Arab conquest meant that Rabbanite communities looked to one of the three *yeshivas* (academies) located in Baghdad or Palestine for guidance on theological problems as well as more practical matters such as communal and property issues.[30] The *yeshiva* head (*gaon*) considered the opinions of members and wrote responsa as formal statements that had the character of official resolutions.[31] Several geonic responsa from the Genizah provide details concerning textile commerce and consumption.

Goitein's monumental multiple volume work covers extensive evidence describing silk production, exchange, and use in contemporary life.[32] Stillman expanded Genizah textile scholarship through her dissertation examining female attire in medieval Egypt through trousseau lists and other documents from the archive.[33] Olszowy-Schlanger's comprehensive study of Karaite marriage documents, including sixty-five edited and translated manuscripts,

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[29] Stillman 1990, 369.
[30] Goitein 1967-1993, 5-10.
[31] Goitein 1967-1993, 13.
[32] Goitein 1967-1993.
[33] Stillman 1972.

makes evidence concerning textiles available for broader scholarship.[34] A recent article by Gil provides a summary of silk references in eleventh-century Genizah documents.[35]

The cross-Mediterranean character of the luxury textile trade is amply demonstrated by frequent references to *Rūmī* merchants and cloth goods, placing Byzantine silk within a regional context. Early work by Krauss, and subsequently Starr, examined the role of Jews in Byzantium including the textile trade.[36] De Lange summarised documents referring to Byzantium in Jewish life, and published a translation and analysis of Greek Jewish texts in the Cairo Genizah.[37] In a series of investigations, Jacoby examined Jewish participation in the regional textile economy.[38] Recently, Holo explored Jewish involvement in the Byzantine economy as a web of exchange systems.[39]

As noted in chapter 2, the account of Benjamin of Tudela provides a complementary perspective on the Jewish diaspora, and dates from the mid-twelfth century.[40] From Spain, his travels took him to scattered Jewish communities in Mediterranean Europe, Byzantium, and the Islamic world. His observations and census provide important insights concerning the role of Jews in the textile economy of Byzantium and the region.

c. Byzantine sources

Unlike the Islamic and Genizah source compilations described above, a systematic survey of Byzantine textual material pertaining to textiles has yet to be produced. Originally published in 1688, Du Cange's *Glossarium* remains an important reference for textile terms

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[34] Olszowy-Schlanger 1998.
[35] Gil 2002.
[36] Krauss 1914; Starr 1939.
[37] De Lange 1992; De Lange 1996.
[38] For example see Jacoby 1991-1992; Jacoby 2004.
[39] Holo 2009.
[40] Be Tud.

found in Byzantine sources.[41] In 1852, Francisque Michel, a historian and philologist, published a study of historical references to fine textiles.[42] Developed primarily from church inventories and medieval documents, this essay demonstrates how Byzantine and Arabic textile terms were conveyed into the textile lexicon of Western Europe. Sabbe undertook a similar project investigated from the standpoint of trade.[43] The *Byzantinon bios kai politismos* volumes compiled by Koukoules include several textile-related terms and references.[44]

Research concerning Byzantine textile references is largely confined to essays concerning silk. Studies by Jacoby and Muthesius each discussed the meaning of selected textile terms found in middle Byzantine imperial sources.[45] Several other publications considered textile details within the context of selected sources. Commentaries written by Reiske and Vogt in their respective editions of the *BOC* included discussion of some textile terms found in the text. Drawing upon these two resources, Guilland published a more detailed interpretation of some cloth terms in the *BOC*.[46] The *Lexikon zur byzantinischen Gräzität* (*LBG*) is a helpful resource to locate related mentions of infrequently used textile terms, but offers few interpretational insights.[47]

Given this lacuna as compared with Islamic and Genizah source compilations, my initial task was to assemble a corpus of Byzantine material describing textiles. Silk in its many forms and uses appeared in a range of written sources and literary genres dating from the middle Byzantine period. Predominant source types include: *taktika*, regulations, inventories, testamentary documents, histories, chronicles, and other literary forms. In compiling such

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[41] Du Cange 1943.
[42] Michel 1852; see summary by Weibel 1935.
[43] Sabbe 1935a; Sabbe 1935b.
[44] Koukoules 1948-1952, especially 2.1: 204-217; 2.2: 5-96.
[45] Jacoby 1991-1992; Muthesius 1995b.
[46] Guilland 1949.
[47] *LBG*.

disparate data, contextual information contributes to the information gained from direct descriptions. While a comprehensive survey of all textile mentions in Byzantine sources is beyond the scope of this work, the compilation of a representative corpus of silk textile mentions provided here gives insights into material characteristics and usage patterns.

Extensive references to luxury textiles appear in court protocols in which patterned silks provided highly visible vehicles for ceremonial display. While the *BOC* seems to contain an overwhelming quantity of detail, most mentions are formulaic and fall into a discrete number of categories.[48] Among other works composed in the court of Constantine VII Porphyrogennetos, the *De Administrando Imperio* treatise describes precious textiles among imperial goods desired by other nations.[49] The *Imperial Expeditions* text edited by Haldon is an important resource for study of silk in context.[50] The notes to this edition provide a summary of scholarship associated with textile terms mentioned in the text. The garments worn by various dignitaries for imperial banquets described by the *Kletorologion of Philotheos* demonstrate the hierarchical ordering of textile types.[51]

Property and personal documents including wills, inventories, donation acts, and marriage contracts comprise some of the most straightforward and easily interpreted evidence concerning silk. Among aristocratic testamentary documents and *typika*, several refer to valuable silk textiles including those written by Michael Attaleiates, Symbatios Pakourianos and his wife, Eustathus Boilas, and Gregory Pakourianos.[52] Middle Byzantine inventories from monasteries such as Patmos and Panteleemon include a large number of textile articles.[53]

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[48] *BOC,* Reiske.
[49] De Adm Imp.
[50] Imp Exp.
[51] Listes.
[52] *Attal,* Gautier; *Ivir II*, 44; *Ivir II*, 47; *Boilas*; *Gre Pak*, Gautier.
[53] Patmos, Astruc; Act Pantel.

The written sources for Byzantine southern Italy and successor states after 1071 represent additional evidence.[54] For example, a marriage contract dated 1267 contains several references to textiles including silk for both garments and furnishings.[55]

Other written sources include material pertinent to this study. Information about the caravan trade in raw silk comes from Menander's history covering the period 558-582.[56] The author of the Christian Topography described the long distance sea trade in raw silk in the sixth century.[57] The seventh- to eighth-century *Rhodian Sea Law* referred to finished goods.[58] Letters such as those written by Leo of Synada and John Apokaukos include specific information about silk in non-elite use.[59]

References to textiles are frequent in the major histories and chronicles associated with the middle Byzantine period. Authors employed different structural forms ranging from annual accounts to narratives constructed around specific themes. Importantly, textile evidence from these sources requires consideration of rhetorical conventions. In several works, textiles and luxury goods are used symbolically to represent social order or to express cultural perceptions and priorities.

Composed in the late eighth and early ninth centuries both the *Breviarium* by Nikephoros, Patriarch of Constantinople (806-815), and the *Chronographia* of Theophanes the Confessor, included historical accounts referring to silk.[60] Similarly, Leo the Deacon's

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[54] Falkenhausen 2007.
[55] *Syllabus*, 435-436.
[56] Menand.
[57] Kos Ind, Wolska-Conus.
[58] Rh Sea.
[59] Leo Syn; Jo Apok, 99.
[60] Nikeph; Theoph, Mango.

tenth-century *Historia* reported events useful to a history of silk.[61] Covering the interval between 811-1057, the eleventh-century *Synopsis Historiarum* by John Skylitzes contains numerous mentions of silk and other textile goods which are presented in a conspicuous way as compared with other authors. Reporting on the period 976-1078, the *Chronographia* by Michael Psellos provides information about silk and its context of use during the time.[62] Michael Attaleiates' *Historia* recorded events from 1034-1079/80.[63] Niketas Choniates' chronicle is an important historical source for 1118-1206. Although seldom considered at length in the secondary literature associated with silk, this text contains a wealth of information.[64]

The *Vita Basilii* was composed in the mid-tenth century as a *panegyric* of Emperor Basil I. While the text is an idealised representation, it contains several specific mentions of various types of textiles.[65] Written in the mid-twelfth century, Anna Komnene's *Alexiade* includes some references to silk and imperial costume.[66]

In poetry and *ekphrasis*, costly materials were symbolically linked with intangible qualities as part of a larger constructed experience, often with transformational intentions. In the sixth-century account of Hagia Sophia by Paul the Silentary, a silk altar cloth provided a vehicle to portray the emperor and empress joining hands with the mother of God and Christ.[67] In contrast, the funerary vestments described in the sixth-century poem *In laudem Iustini Augusti minoris* by Corippus convey a circumstantial, non-rhetorical account of fine

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[61] Leo Diac, Hase.
[62] *Psellos*, Sathas.
[63] *Attal,* Brunet.
[64] *Nik Chon,* Dieten.
[65] V. Basilii.
[66] An Komn, Leib.
[67] Macrides and Magdalino 1988, 71.

textiles in sixth-century imperial ceremonial practice.[68] The poem appears to have been written in Constantinople for a court audience that could understand the ceremonial and political nuances of imperial succession.[69]

Given the problems associated with interpreting luxury textiles in the context of rhetorical writing, a guide to interpretation is helpful. In an analysis of Paul the Silentiary, Macrides and Magdalino proposed a framework involving four parameters: objective description, literary form, and historical and occasional context.[70] Although defined in terms of *ekphrasis*, this approach can be extended to include the full range of literary sources for the purpose of this analysis. Specifically, the textile mention database is designed to record occasional and historical context as well as literary genre.

In the future, as more sources are accessible in digitised form, data mining applications will make locating textile mentions in context easier and faster. Electronic resources such as the *Dumbarton Oaks Hagiography database* and the *Prosopography of the Byzantine World (PBW)* forecast future research opportunities.[71] Launched recently at the University of Fribourg, the online database, *Artefacts and Raw Materials in Byzantine Archival Documents*, provides a research tool for analysis.[72] The textile database assembled in this project represents an important contribution to material culture studies in the Byzantine world.

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[68] Corippus, 4.
[69] Corippus, 4.
[70] Macrides and Magdalino 1988, 81.
[71] For a brief discussion on the value of quantitative measures for trend analysis in primary sources, see McCormick 2001, 722.
[72] Bender, Parani, et al. 2013.

3.2 Prosopography and Database Methods

In recent decades, methodological developments combined with new information technologies have equipped historians to analyse source evidence more thoroughly and dynamically than in the past. Various research tools are available to aid in organisation and classification of source data in ways that identify connections and patterns associated with historical processes.[73] In searching for a technique that allows extensive but diffuse textile mentions to be accumulated and analysed, prosopography provides a relevant research model.

In its conventional form, prosopography is a method of extracting historical information by compiling information about individuals defined chronologically and geographically based on one or more master criteria.[74] The methodology is inductive, aggregating specific details about individuals to develop generalised perspectives.[75] From its origins in the late nineteenth century, prosopography has been applied in instances when source data are scarce and disbursed, and when subject characteristics are tangible in nature.[76] Although the methodology can be adapted to various historical periods and contexts, the main factor determining selection is the nature of the source material.[77]

The first large scale Byzantine project was the *Prosopography of the Later Roman Empire* (*PLRE*) published in three volumes between 1971 and 1992.[78] Subsequent general resource prosopographies include the *Prosopographie chrétienne du Bas-empire* (*PCBE*) and *Prosopographisches Lexikon der Palaiologenzeit* (*PLP*).[79] Prosopographic methods have also

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[73] Verboven, Carlier, et al. 2007, 37.
[74] Verboven, Carlier, et al. 2007, 39.
[75] Verboven, Carlier, et al. 2007, 67.
[76] Smythe 2008, 179.
[77] Keats-Rohan 2003, 3.
[78] PLRE.
[79] PCBE; PLP.

been applied to a number of more limited works to address questions of historical analysis based on specific topics or source texts.[80]

During the 1980s, two research teams initiated work to fill the gap between the *PLRE* and the *PLP*.[81] A team sponsored by the Berlin-Brandenburg Academy of Sciences published the *Prosopographie der mittelbyzantinische Zeit* (*PmbZ*) in seven volumes covering the period 641-867.[82] Researchers sponsored by the British Academy, and later the Arts and Humanities Research Council, published one volume of the *Prosopography of the Byzantine Empire* (*PBE)* in 2001.[83] Like the *PmbZ*, the *PBE* covers the period 641-867. Subsequent work focused on the period 1025-1180. Since its launch in 2006, the *PBW* has been developed as a web-accessible database.[84] The resource was designed to include data for territories within the boundaries left by Basil II in 1025.

As Byzantinists have gained experience in creating and using prosopographies, earlier efforts provided a foundation for development, with an evolving understanding of conventions and methodologies.[85] Eck described how prosopography enabled progress in historical insights by providing a means to pose large questions that are otherwise hard to determine and difficult to assess.[86] Mathisen discussed how scholars with a variety of specialties and interests could apply new technologies and methods to source materials.[87]

Coincidental with evolving ideas about prosopography, development and application of database technologies have made queries for cross-sectional views of information possible,

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[80] See Smythe 2008, 178.
[81] Treadgold 2003, 945.
[82] PmbZ.
[83] *PBE*.
[84] Jeffreys, Karagiorgou, et al. 2011, Project definition.
[85] Mathisen 2003, 34.
[86] Eck 2003, 17.
[87] Mathisen 2003, 35.

enabling researchers to manipulate data more easily and apply results to new and different kinds of research questions.[88] Over time, the scope of research moved from a narrowly defined set of elite members of society to include a progressively larger set of individuals, both named and anonymous.[89] Nelson described the dynamic aspect of prosopography as an approach that has evolved iteratively based on technologies available, research interests, and a growing body of scholarly work devised by successive generations of scholars.[90]

According to established prosopographic conventions, artefacts are considered in terms of their association with people in order to preserve historical integrity.[91] While historical objects can be studied from the standpoint of the historical persons who produced and used them, restricting research in this way overlooks many details associated with textile descriptions. Development of a textile mention database represents an extension of evolving prosopographic methods to include extensively documented artefacts such as textiles.

Both textiles and individuals share the representativeness problem of historical evidence with a bias toward the elite and exceptional members of a population. However, careful source analysis and pattern detection can reveal information about commonplace items.[92] The conclusion drawn from this comparison is that with certain adaptations, a prosopographic research approach is specifically applicable to development of a textile mention database. As such, the literature of prosopography methods and tools was helpful in structuring this project.

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[88] Nelson, Pelteret, et al. 2003, 163.
[89] Mathisen 2003, 35.
[90] Nelson, Pelteret, et al. 2003, 156.
[91] Magdalino 2003, 46-47.
[92] Verboven, Carlier, et al. 2007, 41.

During the past two decades, several handbooks and websites have been created as resource guides in undertaking prosopographic projects.[93] Verboven advised a two-stage, structured approach with preliminary work including definition of a general research objectives, hypothesis development, source survey, and selection of tools.[94] The actual prosopographic stage involves specific identification of a target population, translation of research objectives into a standard questionnaire, database construction, analysis and synthesis. To yield the maximum benefit from the project, information components need to be broken down into their smallest meaningful units – effectively atomisation of data – so that details can be combined to construct valid generalisations.[95] To reduce the effect of bias from a dominant text or set of sources, the evidentiary network needs to be gathered from a wide range of writing.[96]

A major consideration associated with prosopographic projects is the amount of time and effort required. Carrié considered prosopography to be 'extremely hard, demanding, all-absorbing and tedious'.[97] Cameron described the approach as 'immensely labour intensive, and [it] still depends on detailed and careful analysis of historical sources by specialist scholars'.[98] Experienced practitioners represented the process of designing the logical framework for a database project as challenging because of the need to clarify information to the degree necessary for computer modelling.[99]

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[93] For example, see Nelson, Pelteret, et al. 2003; Short and Bradley 2005; Keats-Rohan 2003; Merry 2003; Keats-Rohan 2007.
[94] Verboven, Carlier, et al. 2007, 47-48.
[95] Magdalino 2003, 46.
[96] Keats-Rohan 2003, 3.
[97] Carrié 2003, 92.
[98] Cameron 2003, xiv.
[99] Short and Bradley 2005, 17.

A rigorously designed and tested prosopographic framework obviates one of the longstanding criticisms of prosopography as ‘narrow and reductionistic, an assemblage of facts’.[100] Prosopography is fundamentally an interpretative process, both in terms of design and in processing data.[101] According to Verboven, ‘application of strict historical criticism to each scrap of source material is essential’.[102] Yet, despite transparent and robust design, uncertainties and ambiguities in the data are inevitable in the process.[103] Nelson advised development of explicit interpretative tools for data entry and coding, as well as a means to note concerns at the record level for reconsideration.[104] The on-going process of evaluation and engagement with source material counters the concern that database approaches are artificial, overly rigid and ‘squeeze’ data into simplistic categories.[105]

Despite these challenges, prosopography has a several of advantages over less formalised methodologies. By nature, the process requires critical and comprehensive use of texts. Further, it can help identify material drawn from earlier sources through structured comparison of evidence. Similarly, prosopography provides a means to evaluate the representativeness of source material. By structuring data in a consistent fashion, this methodology provides a contextual tool to distinguish the commonplace from the exceptional. As a result, prosopography aids in revealing relationships and trends based on structured evidence.

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[100] Mathisen 2003, 34.
[101] Nelson, Pelteret, et al. 2003, 164.
[102] Verboven, Carlier, et al. 2007, 54.
[103] Nelson, Pelteret, et al. 2003, 157-158.
[104] Nelson, Pelteret, et al. 2003, 157-158.
[105] Short and Bradley 2005, 16-17.

3.3 Relational Database Approach

Newer prosopographic projects apply relational systems to develop computer databases that are more flexible and usable than in the past. The main advantage of relational design is the ability to organise and access information in a wide variety of ways.[106] The architecture of a well-constructed database is developed through data modelling. This process entails standardising information elements and defining hierarchical relationships to avoid redundancies.[107]

An appropriately modelled database provides many benefits including the ability to manipulate and order data according to defined criteria and to share contents among applications.[108] Large-scale prosopography projects such as the *PBW* have been developed on a collaborative basis, pairing historians with specialist information technology systems professionals.[109] Such projects require cross-functional expertise and a long-term commitment of resources.

Recent software improvements have made sophisticated database technologies more accessible to individual scholars. Among available development packages, I selected Filemaker Pro as the most appropriate application for this project. The unified file structure provides a common set of tools for integrated development of database 'layers', comprising the system structure, user interface, and presentation of information.[110] This architecture is suited to projects that are relatively unstructured and require an iterative approach.

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[106] Short and Bradley 2005, 11.

[107] The process of reducing data to the lowest possible level of redundancy is called normalisation and is described in a number of technical database sources. Ramsay 2004 provides a helpful resource for database development for humanities applications.

[108] Centre for Computing in the Humanities 2002, 2.

[109] Nelson, Pelteret, et al. 2003, 163.

[110] FileMaker 2003, 2.

To demonstrate how prosopographic methods have been specifically formed into a framework suitable for computer modelling of textile mentions, the following provides a brief description of the system's logical structure. The textile mention database is designed around two related data sets: the textile mention data form and the textile terminology data form.

a. Textile mention data form

From a database point of view, all textile mentions share a common tree-like hierarchical structure. One mention describes one or more textile object or activity. Each named object or activity comprises a branch that corresponds to one or more groups of attributes. In turn, attribute groups comprise one or more individual attributes. A single textile attribute is the lowest level element in the data hierarchy and corresponds to a factoid in prosopography.

The interface layout for the textile mention data form is included as appendix 3.1. The form is designed to collect specific textile information consistent with the analytical framework for this project, namely: material, textile construction, pattern, and end use. Other data elements include geographic location, qualitative description, and context of use.

b. Textile terminology data form

One indication of the importance of textiles to their respective societies is the large number of specific terms in common use. For Arabic textile terms, Serjeant's extensive glossary is the main reference for Islamic material prior to the Mongol conquest.[111] Similarly, Goitein defined a large number of textile terms in relevant chapters. Although a number of Byzantine secondary works discuss the meaning of selected textile-related words, no author has compiled a detailed glossary of terms.

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[111] Serjeant 1972.

Appendix 3.2 shows the database layout used to gather information about textile terms. The form provides the basis to consolidate information about meaning and usage as well as to categorise words by production stage as discussed for the textile mention data form. By tying textile term definitions together with associated mentions, the database provides a means to produce 'key word in context' analysis. This approach is an example of how data modelling can combine database and textual analysis tools together in a hybrid design.[112]

3.4 Guidelines for Interpretation

In addition to a formalised structure for data collection as described above, a developed methodological approach requires defined conventions to guide the process of interpreting information. By nature, the process of historical inquiry involves interrogation of widely varying sources. However, the degree of abstraction involved in creating a structured database means that source evidence must be considered carefully in the process of data compilation as well as in interpreting the consolidated corpus.

To ensure that all data are handled in a consistent manner, explicit guidelines for interpretation are helpful. Because evidence is mainly descriptive and occurs in the form of mentions, each attribute is treated as an independent data element and is assigned equal weight. Judgement of the veracity of information is part of the analytical process and is based on patterns defined by the aggregated corpus.

Given the nature of the evidence, it is neither possible nor desirable to restrict information gathering to luxury silks. In some texts, silk descriptions appear together with

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[112] For a discussion of combined modelling approaches for humanities research, see Bradley 2005; Short and Bradley 2005.

details about other fabrics. Consequently, this study takes a broader approach by gathering information about all types of textiles. The aim is to exploit information gained from primary sources by applying a consistent framework to structure and order information. The resulting corpus provides an aggregated population to discern patterns and perform analysis.

a. Process of description

In developing specific research guidelines, it is helpful to consider how textiles were depicted in written works and the kinds of descriptive conventions applied. Even a cursory review of the sources indicates that textiles were a prominent feature in the regional material culture during the period covered by this study. An obvious feature of historical writing is that tangible goods are visible to us only through description. The process of relaying information depends upon an author's interest, knowledge, experience, and intended audience as well as choices and the ordering of information.[113] By nature, all textiles have a number of basic qualities in common. The discrete set of possible raw material components used in textile production can be combined in a variety of ways to produce distinctive materials.

b. Problem of terminology

Reference to common images is evident in the extensive terminology associated with textiles. Through the lexicon of textiles, we see a rich environment of different types and purposes. Many fabrics have specific names and identities that would have been understood in a contemporaneous setting. A confounding problem of historical textile studies is how to interpret the meaning of specific terms. Philologists have long tried to clarify the meaning of

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[113] Webb 1999, 62.

textile terms in primary sources with limited success.[114] For example, in his preface to *BOC*, Vogt observed that it is not possible to know the precise nuances of textile-related terms.[115]

Probing more deeply, there are several reasons why textile terminology presents such a challenge. First, sources are far from explicit in the use of textile lexicon. With few exceptions, authors used specific textile terms in context without elaborated definition or provision of descriptive details. According to Piponnier, a comprehensive study of textile terms would require rigorous research methods covering the technology, etymology, and evolution of language to reach a satisfactory outcome.[116]

Even a well-conceived, cross-cultural effort to construct a glossary of textile terms would face additional challenges. Examination of textile terms in context demonstrates imprecise usage and classification.[117] Some of the terms encountered in this study cover several categories of the same product, making it difficult to discern how the named quality was similar to or different from other distinguishing characteristics.[118] Moreover, textile terminology was not stable, but evolved different meanings over time. Various factors contributed to the migration of meaning including changes in material type, production location, and technology. Piponnier suggested that in general, imitation and substitution of lesser materials led to a decline in the quality of textiles designated by the same term.[119]

In some instances, obscure or ambiguous textile terms may limit research results. Meaning may be irretrievably lost if descriptive details are lacking. Like other specialised lexicons, textile terminology usage can be inconsistent and localised. When referring to

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[114] Lombard 1978, 239.
[115] *BOC*, Vogt, Vol. I, 30.
[116] Piponnier 1967, 878.
[117] Piponnier 1967, 864.
[118] Lombard 1978, 238-239.
[119] Piponnier 1967, 869.

finished textile goods, a number of vague or general terms such as robes or stuffs were commonly used. In spite of these limitations, the textile mention database aids examination of evidence through contextual comparisons among sources.

c. Textile names

One of the most challenging aspects of deciphering textile terminology pertains to textile names. In his examination of Islamic textiles, Serjeant listed a total of 168 names from his compilation of written sources. Among the Genizah sources consulted for a study of bridal trousseau lists, Stillman found more than sixty textile names, sixteen of which were in addition to those included in Serjeant's work.[120] A glossary of Byzantine textile terminology and names would be a valuable contribution to the field, particularly in association with Islamic and Jewish sources.

Textile terms in both Arabic and Greek generally fall into distinct groups. The three categories common to both languages are: descriptive or technique-based terms, names carried over directly from other languages, and geographic appellations. This third category may refer to a district, city, region, or even more generally, a culture. For example, Islamic and Genizah sources both contain numerous references to *Rūmī* textiles. A fourth category found only in Arabic sources was based on honorific or tributary references. Although many of the texts in the Cairo Genizah were written in Hebrew script, the terms associated with textiles were transliterated mainly from Arabic, but also from Greek in a few instances.

As a group, these toponymic textile terms pose the greatest challenge to interpretation. In many instances, ambiguous usage makes it difficult to differentiate between stuffs described as originating in a particular location from descriptions meant to indicate a style or

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[120] Stillman 1972, 19.

fashion of dress.[121] While a geographic reference might be authentic, place names frequently were used in conscious imitation. For example, some historical toponyms such as damask, muslin, and tabby have been carried into modern use, but with meanings that have changed greatly over time. Today muslin is an inexpensive, loose cotton, but Marco Polo described Mosul cloth as woven with silk and gold.[122] This reference provides an indication of the migration of meaning and tangled references that are often associated with textile trade names.

In summary, this chapter describes a data methodology to gather widely distributed information into a consolidated resource. Textiles were a dominant feature of the regional material culture and were frequently mentioned in middle Byzantine sources as well as contemporaneous Islamic and Jewish texts. Prosopography provides a model for development of a textile mention database that supports identification of historical processes associated with silk in terms of production and consumption characteristics. The following chapter applies the database methodology to a broad range of Byzantine sources.

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[121] Stillman 1972, 25.
[122] *Mar Pol*, I.60; see I.62 n. 3 for discussion of changed meaning for muslin.

PART I: CHAPTER 4 - TEXTILE MENTION DATABASE ANALYSIS

4.1 Overview

The purpose of this chapter is to interpret textual evidence in a way that supports direct comparison and analysis of surviving weft-faced compound weave figured silks attributed to Byzantine and other Near East workshops between the sixth and thirteenth centuries. This process is aided by considering written sources from a framework that follows the general sequence of silk textile processes including: material acquisition and preparation, textile construction, pattern reproduction, and use of finished goods. An underlying theme in this investigation is the role of imitation and reproduction in the spread of silk consumption and development of textile technologies.

Following the textile mention definition presented in chapter 3, I have compiled a corpus comprising over 800 descriptive mentions of textiles found in twenty-two Byzantine sources dating from the sixth to thirteenth centuries. These data demonstrate the high incidence of textile mentions in a wide variety of Byzantine texts and provide a general indication of the importance of fabrics to society. A table summarising details by source is included in appendix 4.1. The numbers presented in this analysis are not especially meaningful in absolute terms, but instead provide a means to summarise data and discern patterns on a relative basis. The information comprising the corpus is expanded by mentions from Arabic texts and the Genizah documents concerning the silk trade, including references to Byzantine textiles.

a. Silk terminology

One of the most surprising conclusions from this source analysis is the relative infrequency of explicit references to silk in both prescriptive and historical writing. In these two categories, terms specifically referring to silk appeared only in about eighty instances. In most works, silk was implied through context rather than directly mentioned. To provide a measure of the extent of implied reference, each textile mention was evaluated according to four characteristics that suggested silk: colour, embellishment with precious materials, superlative description, and context. As shown in appendix 4.1, in about half of these cases, two or more characteristics appeared together, providing additional information suggesting silk. Considered this way, silk was implied in an additional 450 instances.

For the purpose of comparison, other textile fibres such as wool, linen, and cotton were explicitly named in a total of sixty instances. An additional sixty mentions presented the material described, but not named, in contexts that were very humble or lowly, suggesting that the fibre type being discussed was not silk.[1]

Silk was explicitly identified in Byzantine sources by one of three terms: *serika*, *blattia*, and *metaxa*. In the majority of mentions, references to silk were used generically and were not elaborated. Various scholars have discussed silk terminology and concluded that the words were part of an evolving lexicon, but were probably synonyms.[2] The information contained in the database corpus provides additional insights into the use and development of silk terminology in Byzantine writing.

1. *Serika*

While the incidence of both *serika* and *blattia* was nearly equal among the sources surveyed, the terms developed and were used in different ways. *Serika* was the word used by Theophanes of Byzantium in the second half of the sixth century to describe the transfer of sericulture technology to the empire.[3] As shown in appendix 4.1, *serika* was the principal

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[1] For discussion of the clustering of mentions around luxury textiles, see chapter 4.2.
[2] For example *Imp Exp*, 205-207 n. (C) 173; Jacoby 1991-1992, 458 n. 29.
[3] *Theo Byz*, 4, 270, 3.

term for finished silk goods employed by all historians from Nikephoros (ca. 750-828) to Choniates (ca. 1155-1217).

The term *holoserika* appears in the seventh- or eighth-century *Rhodian Sea Law* referring to the reward due to sailors for salvaging valuable silks.[4] In translations of Byzantine sources, the term has been conventionally interpreted as full, whole, or all silk, meaning that both the warp and weft consisted of silk.[5] In a comprehensive analysis of silk terminology centred on the late Roman period, Schmitter traced the appearance of the Latin word *holosericum* to the early third century.[6] At the time, the word referred to continuous filament silk as compared with inferior spun silk known as *subsericum*. Schmitter concluded that silk had become common enough for the meaning of *serika* to be vague, requiring more specific terms to describe silk quality distinctions and processing stages.[7] Analysis of the *BOC* shows that evolution of silk terminology is also evident for the word *holoserika*, which appeared only in chapters dating from the fifth to seventh centuries.[8]

2. *Blattia*

The word *blattia* provides another example of changing terminology associated with silk. Guilland described the semantic evolution of the term from a purple murex dye derived from shellfish in the late Roman period to a generic designation for silk textiles by the ninth century.[9] However, analysis of the corpus indicates that usage remained ambiguous. Some later sources used *blattia* with reference to purple silk. For example, *De Administrando*

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[4] *Rh Sea*, 40, 4, 6-9. For discussion of the meaning and incidence of *holoserika* in various sources, see *Rh Sea*, 114 note.
[5] *LBG*, 1122.
[6] Schmitter 1937, 224.
[7] Schmitter 1937, 213, 223.
[8] *BOC,* Reiske, I: 89, 404, 405; II: 28, 629; II: 51, 701.
[9] Guilland 1949, 333-338.

Imperio described remuneration to the Pechenegs in *blattia* and other precious textiles in a way that indicates purple silk was involved.[10] Similarly, Anna Komnene used the word with the specific meaning of imperial purple silk in her description of Alexios' gift to Henry IV.[11] In some other texts, *blattia* was combined into a compound word that specifically identified other colours.[12]

Among the seventeen mentions of *blattia* in the *BOC*, seven were for garments, one for furnishings and nine for lengths of fabric for decoration. Nearly all references to *blattia* in the text appeared in chapters dated to the tenth century. The compilation also included two enigmatic mentions of *holoblattia*, both in reference to church singers wearing the ceremonial dress of regiments or imperial guards for the visit by foreign ambassadors in 946.[13] Other variations of the word, presumably with reference to types of silk, are found in the eleventh-century testament of Eustathios Boïlas (*blatenia*)[14] and in the Patmos Inventory dated 1200 (*blattitzin*).[15]

3. *Metaxa*

In contrast to *serika* and *blattia*, the word *metaxa* was often used with the specific meaning of raw silk fibre. Prokopios used the term *metaxa* in his account of the introduction of sericulture to Byzantium.[16] Surviving fragments of Menander's history demonstrate a clear distinction between *metaxa* and *serika*. All discussions of bulk trade in raw silk with the

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[10] *De Adm Imp*, I.6.6-9.
[11] *An Komn,* Leib, III, 10, 4, 3-10.
[12] For examples of mentions of *blattia* in various colours, see *BOC,* Reiske, I: 97, 441; and *BOE*, Koder, 4.3, 8.1, 9.6.
[13] *BOC,* Reiske, II: 15, 577, 589.
[14] *Boilas*, 24.125.
[15] *Patmos*, Astruc, 22.41.
[16] *Prok, De Bello Goth*, Niebuhr, IV, 17.

Sogdians referred to *metaxa*.[17] In contrast, finished goods, such as hangings and gifts, were called *serika*.[18] Usage by Theophanes Confessor is less clear. He wrote *metaxa* when describing the Roman capture of Saracen tents in 528/9 and burning the contents of the Persian palace of Destagerd in 625/6, but *serika* in two instances involving silk cloths.[19]

Use of *metaxa* to refer to woven silk was less common, but was used in certain instances. The term appeared in the Greek version of the fifth-century book of the Armenian Agathangelos.[20] It may have been incorporated in a historicising sense in the hagiographies of Saints Arethas[21] (martyred ca. 520) and Gennadios,[22] patriarch of Constantinople (458-471) in the tenth-century editions by Symeon Metaphrastes. The *Imperial Expedition* treatise referred to a particular type of striped silk garment imported from Egypt as *lorota metaxota*.[23] A marriage contract from southern Italy dated 1267 referred to silk cushions and face veils as *metaxa* rather than *serika*.[24]

This analysis of the three words for silk, *serika*, *blattia*, and *metaxa*, indicates that the meanings overlapped, but that each term had a distinctive identity. *Serika* was a generic word in common use for finished silk cloths. *Blattia* coincided with *serika* in reference to finished silk cloth, but also signalled an imperial association, apparently as a means to convey status. Usage patterns for *mextaxa* show that the word was generally used for raw silk, but might have indicated special features or geographical reference.

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[17] *Menand*, 10.1, 24; 10.1, 50; 10.1, 56; 10.5, 14.
[18] *Menand*, 10.3, 44; 10.3, 51; 25.2, 66.
[19] *Theoph,* de Boor, 179, 25-26; 322, 5-8; 444, 17-18.
[20] *Agathan*, 121.14.
[21] Sym Metaph, 5.
[22] Sym Metaph, 134.
[23] *Imp Exp*, C.290-291, 293-294.
[24] *Syllabus*, CCCIV, 436.

b. Usage categories

Before analysing silk in terms of production processes, it is helpful to identify the ways in which textiles were described in the historical works. While the nature and style of description varied among different authors, there are striking similarities in the way textiles were portrayed. In addition to literal reporting of historical events involving silk as discussed in chapter 2, analysis of textile mentions demonstrates the extent to which cloth was used as a vehicle for symbolic representation and as a rhetorical device to give figurative meaning.

Use of colour and garments to convey dramatic change in social status was a common rhetorical motif in middle Byzantine writing.[25] Considered collectively, both the formulaic nature of these mentions and the frequency of use are striking. Among the historical works considered in the corpus, there are over 130 instances of textiles used to convey positive and negative symbolic actions. For example, Anna Komnene used textiles and colour to convey complex imagery:

> Such is the way of Fortune: when she wishes to smile on a man she exalts him on high, crowns him with a royal diadem, and gives him sandals of purple; but when she frowns, instead of the purple and the crown, she clothes him in ragged garments of black.[26]

Garment colour, quality, type, and condition were used collectively to convey altered circumstances. Precious purple garments connoted imperial roles while dark colours, poor materials, and inadequate covering of the body signalled a monastic context, a humiliating event or mourning.[27] Arab soldiers and prisoners often were portrayed as dressed in white.[28] Anna Komnene referred to valuable textiles and dyes in a series of passages describing a

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[25] James 1996, 111-123.
[26] *An Komn,* Leib, III, I, 1, 14-19; tr. from *An Komn,* Sewter, 79.
[27] For a discussion of colour terms and Byzantine perception see James 1996, 72-74.
[28] *Leo Diac,* Hase, III.53; *Listes*, 169.20; for discussion of the colour white and Arab prisoners, see *Leo Diac,* Talbot, 102 n. 89.

progression of colour privileges received by Constantine, son of the abdicated Emperor, Michael VII Doukas (1071-1078).[29] Textiles were also used to foreshadow important events. Theophanes Confessor used textiles as a vehicle to presage the plague in 745/6 when cruciform markings appeared on garments and holy cloths.[30]

Another indication of the close relationship of cloth to life experience and material culture was through the use of metaphors referring to textiles. In the *Vita Basilii*, Basil 'grappled with the Bulgarian, and threw him with ease, like a tuft of wool, light and dry'.[31] The *Kletorologion* described how the emperors and senate 'dress in splendid fashion in *loroi*, reflecting the glorious joy of the day, swathing themselves as it were in Christ's winding-sheets'.[32]

Both Psellos and Choniates employed textile motifs to integrate classical references with historical narrative. Choniates referred to the involvement of empress Euphrosyne Doukaina Kamatera (1195-1203) in the affairs of state 'unraveling the machinations woven by a certain Kontostephanos like the threads of Penelope'.[33] Psellos described his approach to historical writing 'so a homogenous pattern is worked out, a tapestry of the finest cloth'.[34] Choniates himself used textile imagery in his definition of history: 'she rejoices at the most elegant of phrases and prefers to adorn herself, not with the pretentious and ostentatious, but with the cloth of plain and simple words'.[35]

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[29] *An Komn,* Leib, III, 4, 5-6.
[30] *Theoph,* Mango, 423, 6-8; *Nikeph*, 67.10-11.
[31] *V. Basilii*, 12.32-34.
[32] *Listes*, 201.12-13.
[33] *Nik Chon,* Magoulias, 519. For an interpretation of Penelope's weaving episode, see Scheid and Svenbro 1996, 68-69.
[34] *Psellos,* Renauld, VI, IX, 26.
[35] *Nik Chon,* Dieten, 3, 55-56; *Nik Chon,* Magoulias, 4.

4.2 Silk Fibre Analysis

Having defined various terms for silk and presented a perspective on the portrayal of textiles in historical work, this analysis now turns to an examination of silk process categories beginning with fibre. As the basic unit of textile structure, fibre is defined as a slender filament or fine strand of sufficient length, pliability, and strength to be spun into yarns and woven into cloth.[36] For textile goods in common use, fibre selection was mainly determined by climatic and geographic conditions. In the middle Byzantine period, textual sources indicate that both wool and linen were used widely. At the same time, cotton gradually became a more common fibre, with increased cultivation tied, in part, to development of the paper industry.[37]

Cotton appeared infrequently in Byzantine sources. Yet in various mentions, the fibre does not seem to have been rare or expensive. In the *BOC*, 100 cotton tunics and 100 pairs of cotton leggings were among the items provided by the *eidikon* for the expedition against Crete in 949.[38] Similarly, cotton garments were the responsibility of the *eidikon* in the *Imperial Expedition* treatise.[39] Chapter 9 of the *BOE* permitted linen merchants to purchase cotton garments for use as undergarments or linings.[40]

Among the Byzantine sources included in the corpus, the relatively low incidence of fibre mentions other than silk is explained by a general historical bias in recording exceptional rather than ordinary and common items. Close reading of the sources conveys specific evidence about the function and performance of various fibres and types of cloth. Choniates

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[36] Mauersberger 1954, 23; for a more detailed discussion of fibre and yarn, see chapter 6.1.
[37] See for example, Amar, Gorski, et al. 2010.
[38] *BOC,* Reiske, II: 678, 4; *BOE*, Koder, 9.1.423-424.
[39] *Imp Exp*, C.294-295; 230 n. (C) 294-295.
[40] *BOE*, Koder, 9.1.423-424.

described how Emperor Manuel I Komnenos, recognising his imminent death, exchanged his soft royal vestments for the black, threadbare cloak of a monk.[41] Some authors conveyed the coarse feel and tattered appearance of monastic dress.[42] Rough, hairy fibres, especially goat's hair, were mentioned several times in association with monks or the poor.[43] Theophanes Confessor demonstrated his contempt for Oumaros ('Umar, the third Muslim caliph) by describing him as wearing a filthy cloak of camel hair in the 634/5 invasion of Palestine.[44]

The properties of silk as both a strong and flexible material were recognised by the military application of *metaxa* silk fibres as bowstrings for hand-drawn low-ballistae and for large bow-ballistae with pulleys, alone, or in combination with spart grass fibres.[45] An account by Anna Komnene suggested that silk garments were included on military campaigns. Finding that he had insufficient iron for his troops at the battle of Lebounion (1091), Alexios equipped some of his men in silken garments that resembled iron in colour for battle against the Pechenegs.[46]

Considering other fibres, the absorbency of linen is evident from repeated mentions of towels in the *BOC*, including linen woven with gold for the emperor's bath.[47] Felt is a non-woven wool textile made by matting fibres into a consolidated mass for padding. Skylitzes described how Emperor Nikephoros II Phokas was sleeping on a mattress of red felt when he

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[41] *Nik Chon,* Dieten, 221-222.
[42] *Theoph,* de Boor, 114, 16-17; *Theoph,* de Boor, 581, 3-4.
[43] *Psellos,* Renauld, VI, Const. IX, 199, 4-7.
[44] *Theoph,* de Boor, 339, 19.
[45] *BOC,* Reiske, II: 670, 1 and 12; 671, 15; 676, 10-11. For a brief discussion of silk for bow strings instead of gut, see Haldon 2000, 273 and n. 110.
[46] *An Komn,* Leib, VIII, 4, 1, 6-8.
[47] *BOC,* Reiske, II: 12, 554-555.

was murdered in a plot.[48] Warriors wore protective felt wrappings on their legs, and the tunics worn by chariot drivers were sewn with protective felt wings behind their thighs.[49]

Several mentions of yarn spinning demonstrate that fibre processing was familiar enough to portray in barbed commentaries. In describing Empress Zoe, Psellos observed that she was not interested 'in the things that appealed to women – looms, distaffs, wool, or weaving'.[50] Recasting a sixth-century historical event to the eighth century, *De Administrando Imperio* relayed an incident in which Empress Eirene, wife of Contantine V (741-775), sent a spindle and distaff to the patrician Narses who was governing Beneventum and Papia. The insult of womanly behaviour so incensed Narses that he sought to undermine the empire.[51] Referring to the mid-1160s, Choniates conveyed his opinion of *sebastos* Nikephoros Chalouphes whom he called 'more effeminate than a woman whose only skill was to spin wool in the women's apartments'.[52]

a. Fibre trade

Arab literary works and the Cairo Genizah contain substantial evidence concerning the regional silk trade in the eleventh and twelfth centuries. A handful of Byzantine sources also provide specific information about trade in raw silk. In addition to Menander's account of the Sogdian silk trade as noted above, the sixth-century *Christian Topography* is written from the author's direct experience. He described trade in Ceylon (*Taprobana*) as a transit point for *metaxa* silk and a variety of other exotic goods. He identified *Tzinista*, probably Southern

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[48] *Skyl,* Thurn, XIV, 22, 280, 10.
[49] *BOC,* Reiske, I: 71, 353; II: 40, 639.
[50] *Psellos,* Renauld, VI, Const. IX, 159, 3-5.
[51] *De Adm Imp*, I.27.23-30; see Comm., 89 n. 27/14-37.
[52] *Nik Chon,* Dieten, II, B I, 75-76.

China, as source of raw silk.[53] He also referred to the land-based caravan silk trade through Asia and Persia.[54] The late tenth-century correspondence of Leo, Metropolitan of Synada includes a reference to silk merchants in the Anatolikon theme.[55]

Chapter 6 of the *BOE* represents the most extensive source of information about raw silk in the middle Byzantine period.[56] The regulations referred to *metaxa* with the specific meaning of silk in a raw state, before degumming and other processing. The *metaxopratai* were dealers in raw silk. Their defined role was to buy bulk quantities of *metaxa* coming into the city and resell the material for processing. They were forbidden from working the material themselves.[57]

Another reference to *metaxopratai* comes from a document containing short notices of tenancy contracts found on the last page of codex *Patmiacus* 171.[58] Consisting of only twenty-seven lines, this brief text provides a glimpse of textile commerce in tenth-century Constantinople. Among the five *ergasteria* (workshops) mentioned in the document, four were associated with various aspects of the textile trade.[59] One workshop (before 957) was formerly occupied by a *metaxoprates*.[60] Other tenants included a linen seller, a merchant of head coverings made of goat hair, and a dealer in imported silks.

Descriptions of raw silk transactions conveyed in Islamic sources, Genizah documents, and the *BOE* all show that the basis for exchange was weight. One reason for close

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[53] *Kos Ind, Wolska-Conus*, II, 45.7; 46.2; XI, 15, 4. Also, see *Kos Ind*, McCrindle, 47 n. 2.
[54] *Kos Ind, Wolska-Conus*, II, 45; II, 46; XI, 14-15. For a discussion of *metaxa* in other sources, see 352 n. 45.
[55] *Leo Syn*, 42.1-2.
[56] *BOE*, Koder, Chapter 6.
[57] *BOE*, Koder, 6.14.
[58] *Patmos*, Oikon.
[59] *Patmos*, Oikon, 347 n. 10. For a discussion of workshops and handicraft production, see Koukoules 1948-1952, II, 1, 235.
[60] *Patmos*, Oikon, 346, 3, 2.

supervision of silk transactions was the potential for fraud by rigging scales. The eparch provided certain guilds, including the raw silk merchants, with weights and measures marked with a seal. The weighting implement associated with silk was the *bolion*. Hendy considered the *bolion* to be a silk balance; Koder translated the term as a silk weight.[61]

Historical sources show that the silk fibre itself could be adulterated to increase weight. The author of an Egyptian *ḥisba*, Ibn al-Ukhuwwa (d. 1329), described various methods of weighting silk: 'Some weight silk with prepared starch, others with melted butter or olive-oil. Some mingle with the skein a quantity of some other material for purposes of fraud'.[62] Among the sixteen paragraphs of regulations pertaining to the raw silk merchants in the *BOE*, twelve referred to consequences for violations. Paragraph 11 is particularly interesting because it set a penalty for price manipulation, a problem also noted in some Arab sources.[63]

To complement our limited information about the silk fibre trade in Byzantium, Arab and Jewish texts provide additional insights. These sources referred to at least seventeen different types of silk fibre. Fibre specialisation was not confined to silk. Genizah documents mention more than twenty-six varieties of Egyptian linen in the Mediterranean fibre trade.[64] Names for different types of silk fibre can be grouped into categories based on quality, geographic location, production stage, and special distinguishing characteristics. Appendix 4.2 provides a summary of attested types of silk fibre. While some details are obscure, we have substantial evidence about the general structure of the silk market and the relationship among different fibre types.

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[61] Hendy 1985, 334; *BOE*, Koder, 6.4.
[62] *Ibu al-Ukhuwwa*, XII, No. 279; tr. from Serjeant 1972, 199.
[63] Serjeant 1972, 200.
[64] Goitein 1967-1993, IV, 193.

b. Silk types in trade

In Arabic and Genizah sources, the most frequently mentioned type of silk was *ḥarīr*, which served as a generic term for silk. In trade *ḥarīr* represented the standard grade of silk and served as the market reference for price and quality.[65] *Ibrīsim* was the second most common type, and the designation seems to have been used interchangeably with *ḥarīr*. Serjeant suggested that the term referred to silk imported from Persia.[66] Gil observed that in the Genizah, silkworms were sometimes called *dud al-ḥarīr* and in other instances *dud al-ibrīsam*, so the terms should be considered synonymous.[67] Referring to the cross-cultural and regional character of the silk trade, a geonic responsum explained that the Greek word *metaxa* meant *ḥarīr* in Arabic, but was called *ibrīshum* by Talmudic sages.[68]

As compared to *ḥarīr*, *khazz* was a superior grade of silk. In Arabic literary sources, *khazz* was mentioned prominently to indicate high quality fibre content. Merchants' letters in the Cairo Genizah indicate that *khazz* silk sold at a significant premium to *ḥarīr*, roughly double the value of the standard grade.[69] Less commonly mentioned, *jizi* was another premium grade of silk, possibly shipped in the form of cocoons.[70] According to Dozy, the name was derived from *jiz*, meaning chrysalis, and referred to fibre extracted from the best part of the silkworm cocoon.[71] At the opposite end of the quality spectrum, *khazash* was an

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[65] Goitein 1967-1993, I n. 53, 454.
[66] Serjeant 1972, 89.
[67] Gil 2002, 31-32 n. 9.
[68] Assaf 1928, 155f; in Gil 2002, 31.
[69] Goitein 1967-1993, I n. 53, 454.
[70] Gil 2002, 34, K 832.
[71] Dozy 1927, Supplement I, 234a.

inferior grade of silk and sold for one-third the price of *ḥarīr*.[72] *Ladh* was another inferior quality of silk produced in Sicily, Iraq, and the Maghrib.[73]

Certain types of silk carried geographic names. *Siqli* silk from Sicily was mentioned frequently in Genizah sources as an inferior grade that sold at a discount. A geonic responsum suggested silk exports from Sicily in the tenth century.[74] A letter dated about 1025 recorded large shipments of Sicilian silk to Egypt in the early eleventh century.[75] Silk from Amalfi in southern Italy was mentioned in a letter dated 1046.[76] References to *sūsī* silk are ambiguous and could refer either to Susa in north-western Iran or to the city by the same name in the Maghrib. Writing in the late ninth century, the Arab historian al-Yaʿḳūbī considered *qābis* silk from the Maghrib to be the finest quality available.[77]

Ḥarīr andalusi appears to have been one of the main products traded between Muslim Spain and Egypt as well as spun silk, *iltiquat andalusi*.[78] *Ḥarīr shāmi* was a type of silk from either Syria or Palestine and was superior to *khazash*.[79] *Ḥarīr ghūtī* may have referred to silk from the fertile plain surrounding Damascus.[80] *Lanas* or *lenas* was identified by Goitein as Indian red silk.[81] Glossy *zaytuni* silk (*zaytuni mujalla*) from Zaytun (Quanzhou) China was mentioned occasionally in Genizah documents.[82] Silk from Constantinople (*ḥarīr qustantini*) was discussed in a letter from Jerusalem written by Moses b. Jacob in 1053, who asked that

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[72] Goitein 1967-1993, I n. 53, 454; *khashaz* and *khazzaj* were other transliterated forms of the word.
[73] Goitein 1976, 221-224; Gil 2002, 34, K 599; *ladh* was also known as *lasin*.
[74] Ginzberg 1909, II.65; in Gil 2002, 33.
[75] Gil 2002, 33, K118 a.
[76] Gil 2002, 33, K 246.
[77] Gil 2002, 33 n. 22; Serjeant 1972, 180.
[78] Gil 2002, 32; Goitein 1967-1993, I n. 53, 454.
[79] Gil 2002, 32, 33.
[80] Gil 2002 32.
[81] Gil 2002, 32; Goitein 1967-1993, I n. 53, 454.
[82] Goitein 1967-1993, I n. 53, 454.

seven *ratls* of dyed silk be sent to him from Egypt, but only if the silk was of superior quality.[83]

Considering the *metaxopratai* in terms of a regional trade network provides additional insights into the nature of their role as traders within the Byzantine silk industry. Although specific details are limited, collective evidence from Arab and Genizah sources indicates large-scale westward expansion of commercial sericulture in the region from the eighth through the twelfth centuries. While we do not know the source of Byzantium's silk, written evidence suggests that the material was widely available. The broad geographic range, apparent volume and incidence of transactions demonstrate a robust and sophisticated regional industry. Standard practices including pricing based on grades of material and the many types of specialty fibres provide additional evidence for a highly developed marketplace.

c. Fibre processing

1. Filament silk

Specific terms for silk preparation activities are included in only a few Byzantine sources. For example, fibre processing was mentioned in a document from John Apokaukos.[84] Chapter 7 of the *BOE* referred to the guild of the *katartarioi* as processors of raw silk. Unlike some other chapters, the regulations themselves contain few clues about the specific work performed by guild members.[85] Because the *metaxopratai* were forbidden from processing silk, we can infer that one role of the *katartarioi* was to reel raw silk. According to Lombard's

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[83] Gil 2002, 33, 460.
[84] *Jo Apok*, 99.10.
[85] *BOE*, Koder, 7.1.

analysis the word was derived from Latin *catharteum* and Greek *katharteon serikon*, meaning silk that required cleaning.[86]

Arab and Genizah sources indicate that the silk fibre trade in the region included dried cocoons as well as reeled fibre.[87] Some accounts described the process of unreeling cocoons as a specialist task that required experience. A letter from a merchant in Alexandria advised his correspondent in Old Cairo not to relocate unless trustworthy unravelers were available to reel a small diameter fibre.[88] There are also indications that some reeling was performed as a cottage industry. Genizah documents show that some women performed this task on a small-scale basis in their homes.[89] An early fourteenth-century didactic work involving silk cultivation and fibre processing by Manual Philes described various operations in what seems to have been a home-based or small-scale producer in a Byzantine context.[90]

Other processes to prepare silk for dyeing and weaving involved sorting, degumming, cleaning, bleaching, manufacture of yarns, and insertion of twist. In his chronicle for 965/6, the Persian historian Miskawayh described a mechanical device for spinning silk.[91] Although the account does not support a reconstructive view of the machine, the specificity of description involving a series of hooks and distaffs to maintain tension on the yarn for insertion of twist evidently referred to a device used by professional silk processors at the time. In particular, the account mentioned glass hooks on the machine that would have provided a smooth surface for the movement of silk yarn.

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[86] Gil 2002, 34.
[87] For example, see Serjeant 1972, 198-199; Goitein 1967-1993, 104.
[88] Goitein 1967-1993, 104 from TS 13 J 22 f. 30, 20-22.
[89] Goitein 1967-1993, 128.
[90] *Animalibus*, 65-67.
[91] *Miskawayh*, text, II, 230; tr. from vol. V, 244.

Yarn characteristics have a significant effect on the appearance and function of woven textiles.[92] The *Mahasin al-Tidjāra*, written before 1175, described the ideal characteristics of silk fibre prepared for weaving:

> The best variety is pure and lovely-coloured in kind, free of all variations (in colour or texture) and stains which confuse some of its threads. The thread should be of one shape, and not some coarse and some fine, nor bulging. Good quality is recognised by the heaviness in weight and whenever I have seen a web of a heavy weight, it is better.[93]

Paragraph 8.2 of the *BOE* contains a series of compound words that combine numerical references for six, eight, ten, and twelve with '*polon*'. The regulations forbid manufacture of '*polon*' in units of six or eight, but permitted ten and twelve according to certain requirements. Most scholars have associated these terms with garment construction such as the number of pieces or gores joined together.[94] Given the context of use, however, the term probably applied to yarn fineness, with a low value corresponding to a finer diameter, similar to the modern use of denier.[95] The term '*polon'* also appeared in the *Kletorologion of Philotheos* with reference to a type of yarn.[96]

2. Spun silk

Two chapters of the *BOE* refer to particular types of workshops under the umbrella of particular guilds. Paragraph 6.15 in the chapter for *metaxopratai* dealers of raw silk mentions the *melatharioi*, who were forbidden from trading in silk, but performed some unknown function in the silk trade.[97] In the chapter for the *katartarioi* raw silk processors, paragraph 7.2

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[92] For details pertaining to silk processes see Muthesius 1989a; Hooper 1928, 33-47.
[93] *Dimashki*, 25; tr. from Serjeant 1972, 201.
[94] *BOE*, Koder, 8.2; *BOE,* Freshfield, 245; *Imp Exp*, 217-219 n. (C) 226.
[95] Muthesius 1995f, 292; see *Imp Exp*, 218 n. (C) 226.
[96] *Listes*, 127.14-15; χιτὼν λευκὸς σὺν ἐπωμίοις καὶ πώλοις χρυσοϋφάντοις λαμπρῶς ἀμφιάζεται.
[97] Simon 1975, 39.

refers to the *metaxarioi.*[98] According to the text, *metaxarioi* employed women as well as men, a possible reference to the spinning of silk fibres. Identification of spinning as a female domestic occupation is frequent in Byzantine sources where it assumed symbolic meaning to represent female virtue, modesty and diligence.[99] Women also spun in and out of their homes for pay. In one example, Choniates relayed that Alexios III accused his wife, Euphrosyne, of adultery. She was led out of the palace 'dressed in a common frock, the kind worn by women who spin for daily hire'.[100]

To consolidate the loose filaments left over from the reeling process into yarn, the tangled silk floss is combed to remove waste and debris, and to align fibres.[101] The processed material is then spun like other discontinuous fibres. The resulting yarn is silk in name, but the quality of the material is inferior in several respects. It lacks the fine, 'silky' appearance of filaments and the smooth feel. Even if finely spun, silk yarns appear 'hairy' as compared with filament silk and tend to pill with abrasion and wear.

In general, spun silk was a cheaper substitute for reeled silk and was used in ways that imitated the material. Lopez suggested that both the Arabic and modern Italian words for silk floss, *qatarish* and *catarzo* respectively, come from the Greek word *katartarioi*.[102] Goitein noted the use of the word *qatarish* in an eleventh-century business letter referring to floss silk.[103] The distinction between filament and spun silk was stressed in the *Imperial*

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[98] Simon 1975, 36.
[99] For example, see Talbot 2001, 126; Connor 2004, 164-165.
[100] *Nik Chon,* Dieten, 488, 39-43; tr. from *Nik Chon,* Magoulias, 268.
[101] CIETA 2006, 18.
[102] Goitein 1967-1993, I, 418 n. 27.
[103] See Goitein 1967-1993, I, 104.

Expeditions treatise where *prokrita kathara* was used to indicate 'pure' filaments as compared with either spun silk or a composition of mixed fibres.[104]

The sources covered in the corpus contain several mentions of *koukoularikos*. This material has been translated by various authors as coarse, raw, or spun silk.[105] However, closer definition of the term is necessary for interpretation. Woven into textiles, 'raw' or 'course' silk typically refers to untwisted *grège* yarn in which the sericin coating has been retained to provide strength and body for weaving.[106] Degumming is performed after a textile has been cut from the loom.[107] Rather than raw silk, the usage context in many mentions indicates that *koukoularikos* referred to spun silk, a cheaper version of cloth made from filament silk.

Among the garments provided by the *eidikon* for the expedition against Crete were 100 *koukoularikos* tunics and 100 pairs of *koukoularikos* leggings.[108] *Koukoularikos* was mentioned in a tribunal act among documents attributed to Demetroios Chomatenos (ca. 1216-1236).[109] Among the various types of textiles mentioned in the text were twenty lengths of *koukoularikos* fabric for monastic clothing. The 1142 Panteleemon inventory includes a *koukoularikos* cloth decorated with a pattern of lions.[110] A marriage contract dated 1267 also referred to a silk veil of *koukoularikos*.[111]

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[104] *Imp Exp*, C.240, 250; for discussion of the term, see 225 n. (C) 250.
[105] For example, see *LBG*, 871; Jacoby 1991-1992, 474 n. 118; Koukoules 1948-1952, 25 n. 1.
[106] CIETA 2006, 19.
[107] CIETA 2006, 19.
[108] *BOC,* Reiske, II: 678, 4, 8.
[109] *Dem Chom*, 84, 6, 69.
[110] *Act Pantel*, 7, 74.18.
[111] *Syllabus*, 304, 436. A variant spelling appears in the text as: κοκουλλάκιος.

An indication of the relative value of *koukoularikos* in a Byzantine context is obtained from a marriage contract published by De Lange.[112] The document, dated 1022, was written in the town of Mastaura, in the Byzantine region of Lydia. Among the bride's valuables was a double-faced red dress of *koukoularikos* valued at one and a half gold pieces, comprising just 4% of the total value of movable goods.[113] The dowry listed at least fourteen textile items for garments and the household valued between 0.5 and 2 gold pieces. On a relative basis, the spun silk dress was less valuable than a veil with a silver clasp listed at 2 gold pieces, but more valuable than other dresses recorded at 1 gold piece each.

d. Fibre combinations

In addition to spun silk alone and with other fibres, half silks were also mentioned in Byzantine sources. Such cloths have a long history in the empire dating from the introduction of silk to the region.[114] Textiles woven from a combination of silk and another fibre had the advantage of economy, since a cheaper fibre type was used for either the warp or weft. In the *Broumalion* ceremony described in the *BOC*, both the *protospatharioi* and the *spatharokandidatoi* were given either a length of *molchamion* or a striped robe.[115] The Greek word *molchamion* was equivalent to the Arabic term *mulḥam*, a half silk widely cited in Islamic writing.[116]

Analysis of the types of *mulḥam* described in various sources indicates that the cloth varied widely in construction technique and value.[117] Mention of half silks was common among documents from the Cairo Genizah and references are found in letters, wills, and

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[112] De Lange 1996, 1-10. 7, 30.
[113] De Lange 1996, 6, 30. Also, see 7 n. 30.
[114] Jacoby 2004, 209.
[115] *BOC,* Reiske, II: 18, 607, 9-12; ἀνὰ μολχαμίου βηλαρίου α′, εἴτε καὶ ἀβδίου.
[116] Serjeant 1972, 255; Jacoby 2004, 209 n. 62.
[117] Serjeant 1972, 255; Dozy 1845, 60; Dozy 1927, II, 522.

ketubbā among persons with relatively modest amounts of property.[118] Genizah documents also referred to the occupation of *mulḥim*, as a specialist weaver who wove with a warp of silk and a weft of another material.[119] In some instances, the quality of the material was valuable enough to be included among recorded gifts between rulers. *Mulḥam* appeared in at least three instances in the *Book of Gifts and Rarities*, according to which it was among the valuable textiles sent from Sassanian ruler Khosrau II to Emperor Maurice (582-602).[120]

e. Metal yarns

In addition to the fibre-based materials discussed above, metallic yarns were conspicuously mentioned in almost every source included in the corpus.[121] Gold was the usual metal applied to textiles. The *BOC* contains only two references to silver embroidery.[122] Techniques for incorporating precious metals into textiles are ancient, with archaeological evidence dating the practice to the Bronze Age.[123] In a recent article, Gleba surveyed a number of descriptions of gold textiles from Greek and Roman textual and epigraphical sources dating from the classical to the early Byzantine period.[124] While drawn gold wire and flat metal strips were sometimes used for textiles at the time, they are not well-suited to applications requiring flexibility and drape. In order to produce a more pliable cloth, thin strips of beaten gold were wrapped around an organic core such as silk, leather, or gut.[125]

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[118] Gil 2002, 35 n. 53; Stillman 1972, 23; Goitein 1967-1993, IV, 339; 464.
[119] Goitein 1967-1993, 104.
[120] *Gifts*, 62-63.5.
[121] For the incidence of metal use in textiles, see appendix 4.1.
[122] *BOC,* Reiske, II: 41, 641.
[123] Gleba 2008, 61.
[124] Gleba 2008, 61-63. For other Greek and Roman literary sources referring to gold, see Wild 1970, 39-40.
[125] Gleba 2008, 61-63.

Byzantine sources include two mentions of imperial workers in gold textiles. In addition to the fire in the *chrysoklabarion* mentioned in chapter 2,[126] the *Kletorologion of Philotheos* described the processional order for three occupations associated with the *Chrysion*: the imperial tailors, the gold embroiders, and the goldsmiths.[127] This grouping suggests that it was the goldsmiths who made the gold yarn used by the imperial workshops.

In addition to producing new gold embellished silks, the imperial gold workshop maintained and renovated existing imperial textiles. The alleged actions of Emperor Michael III (842-867) demonstrated that gold woven or embroidered textiles could be melted down to recover precious metals. Both the *Vita Basilii* and Skylitzes' history described how Michael gathered gold vestments belonging to the emperor and high officials and gave them to the *eidikos* to melt down.[128] According to these accounts, Michael's death averted possible destruction of the garments and they were restored to the palace.

Despite the bustling trade in textile fibres and yarns documented in Islamic and Genizah sources, there is no explicit mention of transactions involving metal yarns. While trade in metal yarns is uncertain, Arabic texts contain extensive references to gold textiles. The prominent use of metals in textile products is apparent from the descriptive terminology associated with their use. The glossary to Serjeant's book includes fifty-one Arabic terms referring to gold embellishment through a wide range of processes involved in fabric construction including yarns, weaving, embellishment and finished goods.[129] A few examples are: gold thread (*dhahab maghzul*), woven with gold (*mansudj bi-dhahab*), gold *dabīḳī* brocade (*dabīḳī al-tamim al-mudhahhab*), borders embroidered with gold (*mu'lam muthakkal*)

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[126] See chapter 2, fn. 217.
[127] *Listes*, 133.9-10.
[128] *Skyl,* Thurn, V, 10, 97, 52; *V. Basilii*, 29.23-26.
[129] Serjeant 1972, 242-263.

and curtains embroidered in gold of perfect workmanship (*sutūr mudhahhaba muhkama al-sana'a*).

f. Fibre summary

As this analysis has shown, the properties and performance characteristics of various fibre types were a feature of the material culture of the middle Byzantine period. At the time, trade in silk was extensive with a hierarchy of silk types ranging from premium grades to materials of inferior quality. Considered together with Islamic and Genizah sources, the *metaxopratai* regulations in the *BOE* suggest that the silk industry in Constantinople was oriented toward the regional fibre market with importers from a variety of locations. The inference is that as wholesale dealers, the *metaxopratai* were specialists in grading, buying, and selling various types of fibres through market-based transactions.

To prepare silk for weaving, the *katartarioi* performed a number of processing steps based on customer requirements and market demand. A variety of silk yarn types were produced with different qualitative and performance characteristics. Imitation and fraud were features of the market for silk, demonstrating its value and the need for supervision by the eparch. Unlike some other types of precious materials, silk is a divisible good that could be used in small quantities for decoration, spun as silk floss, or woven with other fibres. Consequently, silk materials were not confined to elite members of society, but functioned as a relative luxury available to a broader population in Constantinople and elsewhere in the empire.

The use of precious metals, principally gold, in textiles is prominent in all of the cultures included in this analysis. Despite the visibility of gold in finished products, applied either through weaving or embroidery, there is no mention of trade in metal yarns. Only imperial sources hint at the production of metal for textiles in the imperial palace workshop.

Given the high value and weight associated with metal yarns, they were presumably manufactured on a local basis or as part of yarn preparation in some workshops.

4.3 Textile Analysis

Having considered evidence for the trade in silk fibre, and the processing of silk and metal yarn components, this analysis now turns to an examination of source information for textile production. Chapter 8 of the *BOE* provides valuable information about the work of the *serikarioi*, the producers of silk cloth. The main challenge associated with this chapter is interpretation of specific terms that have few mentions in Byzantine writing. Despite this difficulty, it is evident that the work of the *serikarioi* involved at least three distinct processes: dyeing, weaving, and tailoring garments for sale to the *vestipratioi*, the silk garment merchants. Each of these distinctive processes represented a group of specialist occupations, and required training and skill, as well as oversight to plan and coordinate work. The following discussion is focused on the work of dyers and weavers.

a. Dyeing

Dyeing of cloth components can occur at one of three stages: unspun fibres before consolidation into yarn, skeins of yarn prepared for weaving, and woven cloth after it has been removed from the loom. Among these, piece dyeing is the most economical way to colour a length of cloth. Skein dyeing produces yarn elements of different colours for combination on the loom. According to the framework defined by the *BOE*, dyeing of fibre and skeins could have been conducted by the *katartarioi* as part of their fibre and yarn processing work. Chapter 8 of the regulations indicates that at least some dyeing was managed by the *serikarioi*.

The occupation of the dyers is among the best documented of the textile trades among the sources considered in the corpus. In addition to valuable murex stuffs, a wide variety of other dye materials were traded throughout the region. For example, Armenia was famous for a brilliant crimson dye known as *ḳirmiz*, which was traded widely in the region, and is noted in several Islamic sources.[130] Chapter 10 of the *BOE* itemised some of the dyestuffs handled by the *myrepsoi*, the dealers in perfumes and unguents, including indigo and yellow wood for dye.[131]

Genizah letters described the sale of brazilwood, a red dyestuff, to *Rūmī* merchants. In 1085 a Tunisian trader boasted that he made a 150% profit on the sale of brazilwood to a merchant from *Rūm* at a port in Palestine.[132] A letter from Alexandria dated about 1060 reported the strange buying habits of the *Rūm*. These merchants bought indigo and brazilwood at auction for exorbitant prices and did not distinguish between high quality and inferior goods.[133]

In addition to dyestuffs, other chemicals were also involved in colouration processes. Describing the alum deposits mined in Upper Egypt, Ibn Mammātī (d. 1209) explained that the material was taken to Alexandria where it was sold to *Rūmī* merchants:

> It is a stone which is needed in many things, the most important being dyeing. There is some demand on the part of the *Rūm* for their requirements; for they cannot do without it nor avoid using it.[134]

While we have little information about the actual work involved in professional dye processes, the industry was notable for its noxious smells and hazardous effluents. From the

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130 For example, see *Iṣṭakhrī*, 188; tr. from Serjeant 1972, 64.
131 *BOE*, Koder, 10.1.462-464.
132 Goitein 1967-1993, I, 45; Bodl. MS Heb. B 3 (Cat. 2806).
133 Goitein 1976, 45-46; BM OR 5542, f. 27, ll. 10-13.
134 *Mammātī*, 23; tr. from Serjeant 1972, 162-163.

Cairo Genizah, a legal inquiry submitted to Nagid Abraham Mimonides (d. 1237) referred to one such environmental problem. A dyer had converted a house in a residential district into a workshop and the quantity of black smoke from the fireplace caused nuisance to the neighbourhood.[135] In Constantinople and other cities, dyers were often grouped together with tanners and castigated for the public hazards of their occupation. In about 1150, Michael Choniates reflected this sentiment, refusing to permit Jewish tanners and dyers to dwell in his diocese.[136]

In Byzantine sources, the high rate of Jewish participation in the dye industry is evident from various texts, in part because the community was subject to restrictions and exclusions, as well as periodic persecution.[137] Describing the denominational and ethnic division in various occupations, Goitein noted the high rate of Jewish participation in the textile industry throughout the region, especially in silk work and dyeing.[138] A Genizah document described how a Jewish silk dyer fled Byzantium to seek financial support in Egypt after he was accused of spoiling a precious fabric.[139] He was severely punished and his children taken from him until he could reimburse his lender. Discussing the Islamic literary works in his compilation, Serjeant observed that Jews seemed to have possessed special knowledge of technical colour processes, and that dyeing was their monopoly.[140]

As mentioned above in chapter 2.5, Benjamin of Tudela's census is an important source for Jewish occupational participation in the textile industry. He reported that there were 2,000

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[135] Goitein 1967-1993, I, 100; from *Maimuni*, 158-160.
[136] *Mich Chon*, I, 53; tr. from Starr 1939, 224-225.
[137] Starr 1939, 1-10; Holo 2009, 9-23, 163-171.
[138] Goitein 1967-1993, I, 100.
[139] Goitein 1967-1993, I, 50, UCL Or 1081 J 9. For a revised translation, see Jacoby 1991-1992, 482 n. 169.
[140] Serjeant 1972, 6.

Jews (meaning families), mostly skilled artisans in silk and purple cloth, in Thebes and throughout Greece.[141] The extent of Jewish participation in the trade was summarised in a reponsa by Rabbi Solomon ben Adreth of Barcelona.[142] He described the Jews of Spain as handling products including dyers' woad and purples:

> The majority of the Jews eked out their living, mostly in huckstering and peddling amongst themselves as well as among their neighbours. The trade chiefly consisted in woollen goods - raw or manufactured, silks, scarlets, and other textile wares, dyes, wax, and ostrich-feathers.[143]

b. Weaving

In contrast to dyers, we have little written information about professional weavers or their work processes during the early and middle Byzantine periods. Wipszycka's extensive study of the late Roman textile industry in Egypt was based on papyrus and ostraca recovered from various sites. The material included numerous details about the work activities and products of professional weavers.[144]

The *BOE* mentioned women only in passing as being among the poor silk yarn producers working outside of the guild of the *katartarioi*.[145] The word *gynaikeion*, which in classical Greek described the part of the house reserved for women, came to mean textile workshop in early Byzantium.[146] The term appeared again in the *Basilika* in a title that must have been enacted in the middle Byzantine period, because it had no parallel in Roman codes.[147] According to the law, a fine would be levied against anyone who corrupted a woman

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141 *Be Tud*, 10.
142 R. Rabbi Sol, 47.
143 R. Rabbi Sol, 47.
144 Wipszycka 1965, especially 47-102.
145 *BOE*, Koder, 7.2.352-354.
146 Lopez 1945, 6 n. 3.
147 Lopez 1945, 6 n. 3.

working in a textile factory.[148] An important citation involving women working for pay in the textile industry appeared in an eleventh-century treatise by Michael Psellos. This text described the *panegyris* of Agathe celebrated by women engaged in carding and spinning of wool, and weaving and tailoring of cloth.[149]

To maintain a trained and skilled workforce essential to the exacting requirements of silk production in Constantinople, slaves may have comprised a significant source of labour. Some studies have examined slavery and its increased importance in the ninth and tenth centuries.[150] Dagron noted that slaves fell into three categories, essentially mirroring the social hierarchy of the free.[151] Slaves could transact business on their owners' behalf, taking on the role of *ergasteriakoi*; perform the role of skilled artisans, representing valuable assets; or work as unskilled labourers.[152] The price of highly skilled slaves, including silk weavers, may have been as much as ten times the price of an unskilled worker.[153]

Some Arab and Persian authors wrote extravagant descriptions of textiles produced in their own lands or made elsewhere. The tenth-century geographer Ibn Ḥawḳal stated that every district of the sultan had a *ṭirāz* factory.[154] In a long exposition, he described the various specialities of various cities, and regions and noted the locations and the products made by the sultan's factories. While rich in details about textile characteristics in terms of fibres,

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148 *Basilika*, 54.16.8-9.
149 *Agathe*, 111-122.
150 For example, see Hadjinicolaou-Marava 1950; Rotman 2004.
151 Dagron 2002, 420-421.
152 Dagron 2002, 419-423. Slaves were explicitly permitted admission to the guilds of the *vestiopratai* and *metaxopratai* with their master's guarantee, but were prohibited from the *katartarioi*. See *BOE*, Koder, 4.2, 6.7, 7.5.
153 Dagron 2002, 421.
154 *Ḥawḳal*, 212; tr. from Serjeant 1972, 50. *Ṭirāz* generally refers to textiles produced in state-controlled workshops. These often included woven or embroidered bands of calligraphy.

decorations, and quality, specific production information is scant. The eleventh-century *ḥisba* by al-Saḳaṭī of Malaga referred to fraudulent practices in cloth weaving including an insufficient number of warps and wefts and a finished weight below an expected standard.[155] According to the author, quality could be judged by a dense weave and heavy weight as well as handling the fringes to ascertain the strength of the warp.[156] 'The worst variety is that which has a weak warp, is light in weight, lax of texture, pale of colour, and of bad silk.'[157]

We learn some additional details from the Genizah inventories of silk-weavers known as *qazzāz*. In addition to a house and instruments, the assets left by a silk-weaver to his sons included raw materials and half-finished products.[158] In another Genizah inventory a woman left equipment for silk weaving to her daughter.[159] An inventory of a silk-weaver, dated 1157, contained more than thirty-two workshop items. The weaver possessed four looms, three combs for silk-weaving, three cylinders of wood on which woven materials were rolled, two irons, one for the pressing of robes and another for the pressing of fabrics worn as turbans, wickerwork baskets full of warps, various quantities of bleaches, linen woven together with silk, a small pot with weaver's reeds, and copper threads covered with silver.[160] This last item suggests an inexpensive means of imitating more expensive metal yarns woven with silk.

c. Textile description and names

As compared with Serjeant's extensive study of Arabic textile names discussed in chapter 3, the number included in the Byzantine corpus is far fewer with only about thirty specific types identified. A survey of more texts would certainly contribute additional textile

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155 *Saḳaṭī*, 62; Serjeant 1972, 200.
156 *Dimashki*, 25; tr. from Serjeant 1972, 201.
157 *Dimashki*, 25; tr. from Serjeant 1972, 201.
158 Goitein 1967-1993, 264, Bodl. MS Heb. a 2 (Cat. 2805), f. 9.
159 Goitein 1967-1993, 128.
160 Goitein 1967-1993, 86.

names. Factors that may have contributed to a more limited Byzantine lexicon may include the empire's reduced cultural and geographic boundaries after the Islamic conquest, and uneven survival of written evidence. As compared with Byzantine texts, the writing style and encyclopaedic approach employed by some Islamic authors at the time meant that many textile words were included in expansive descriptions. Nevertheless, close analysis of terms in context and integration of references with relevant Arabic and Jewish sources demonstrates patterns of Byzantine production and consumption.

1. Descriptive qualities

The textile names that are most easily interpreted today were based on particular descriptive characteristics. Examples from Arabic sources include *qalamūnī* (peacock-like, iridescent), *ḥibara* (striped), *ṭirāz* (embroidered) and *mukhaṭtam* (checked).[161] The corpus includes some Greek terms that referred to striped cloths including *lorota* and *abdia*, an Arab-style striped cloak.[162]

2. Fibre type

In Byzantine sources, one of the most frequent ways of referring to fabrics in common use was to name them by their fibre type. Linen textiles were widely cited in a number of sources with various terms used to describe linen cloth.[163] Examples included descriptive compound words such as blue linen (*linobenetos*),[164] or woven with another fibre such as

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[161] Stillman 1972, 20-25; Serjeant 1972, 216, 261, 255.
[162] For *abdia*, see *BOC,* Reiske, I: 48, 255, 8; *Imp Exp*, C.241-242, 257-258 and 223 n. (C) 242.
[163] *BOC,* Reiske, II: 40, 15; II: 12, 554-555; 45, 672-673; *BOE*, Koder, 13.1.
[164] *Imp Exp*, C175.524.

goat's hair, silk, or cotton.[165] Specific types of linen textiles included *sabana*, which has been translated as a type of cloth for towels.[166] *Sabana* was also used as a term for the linen broadcloth mantles worn by eunuch *protospatharioi* in the *BOC*.[167] *Linomalotaria* appeared among the widow Danielis' gifts in the *Vita Basilii* and was also mentioned in the *Imperial Expeditions* treatise.[168] The widow's gifts to Basil included fine linen *amalia* which may have been a cloth without nap.[169] The same term appeared in the *Imperial Expeditions* treatise together with the adjective *rasika* meaning rough.[170] In the *BOC*, *rasikon* referred to cloth used for making sails.[171]

The sources included in the corpus mention *byssos*, an especially fine type of linen made with delicate yarns that may have appeared semi-transparent.[172] Arab accounts included many references to *ḳaṣab*, a highly-prized, fine linen woven with precious metals for luxury use, often as turbans.[173] Although not mentioned by name, Attaleiates' *Diataxis* included two valuable Saracen cloths, one of which was embroidered.[174] At the opposite extreme, Byzantine sources contain several mentions of sackcloth (*sakkon*), referring to a rough material worn for mourning, punishment, or atonement.[175] Usage context suggests that

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[165] For a summary of terms related to linen, see *LBG*, 940-941; for a comprehensive discuss of linen terminology in Byzantine and other Greek sources, see Georgacas 1959, esp. 255-256.
[166] *BOE*, Koder, 9.7.452; *BOC,* Reiske, I: 41, 215; see *Imp Exp*, 214-215 n. (C) 222.
[167] *BOC,* Reiske, I: 17, 100; 49, 255; 67, 301-302; II: 15, 574.
[168] *V. Basilii*, 74.31-37; *Imp Exp*, 214 n. (C) 222. The term is variously translated as linen tablecloth, fringed cover and rough blanket.
[169] *V. Basilii*, 74.31-37.
[170] *Imp Exp*, C124.
[171] *BOC,* Reiske, II: 45, 674, 7, 11; 675, 7.
[172] For example, see *Skyl,* Thurn, XV, 18, 310, 66; XXIII, 2, 482-483, 87-89; *Attal,* Brunet, 27, 4, 18-19.
[173] Serjeant 1972, 249, 37.
[174] *Attal,* Gautier, 1782, 1793-1794.
[175] *Theoph,* de Boor, 173, 3-6; *An Komn,* Leib, III, 5, 6.

sackcloth was a general category of low quality, coarsely-woven textiles rather than a specific type of cloth.

3. Weave structure

A few textile names in Byzantine sources referred to a specific type of weave structure. Reiske translated the word *trimita* in the *Imperial Expeditions* treatise to mean three-coloured or striped. Haldon carried over this interpretation in his analysis of the text.[176] A more likely explanation is that the word retained its historical meaning as a term for twill weave. In literal translation 'three threads' referred to the number of warps comprising a twill unit as compared with two for tabby weave. The term *trimita* appeared in Roman Egyptian sources including a papyrus dated to the year 363.[177] *Trimitarioi* was an occupation identified in the *Edict of Diocletian* as well as a fourth-century tax receipt.[178] The word also appeared on a second-century inscription found in Pessinous.[179]

The word *hexamitos* is of particular interest to this analysis because of its modern use as a term for weft-faced figured weave silks with a twill binding. Writing in the mid-1800s, Michel described transmission of the word from Greek to European languages through a series of terms including *exametum*, *xamitum*, *sciamitum*, *samita*, *sametum* to the present day samitum, samit, or samite.[180] The term is understood to mean a weave unit of six warps comprising three binding and three main warps.[181] The structure is normally associated with pattern weaving and the resulting cloth would have had a dense weave and heavy feel.

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176 *BOC,* Reiske, Comm., 539 A11; *Imp Exp*, 219-220 n. (C) 229.
177 Wipszycka 1965, 113, *P. Strasb*. 131, 9.
178 Wipszycka 1965, 112 n. 21; 113 n. 22.
179 Broughton 1938, 820.
180 Michel 1852, 106-108; also see Jacoby 2004, 229; Weibel 1935.
181 Becker 1987, 105. In a weave unit of six warps, the structure refers to a 1/2 twill with a 1:1 binding to main warp proportion.

Hexamitos was listed in the eleventh-century *Typikon of Gregory Pakourianos* as an altar covering.[182] The eleventh-century testamentary description of Kale, wife of Symbatios Pakourianos, included a yellow *hexamiton* robe.[183] The *BOE* included a possible related form of the term, *blattia hexalia*, in reference to silks brought for trade by merchants from other nations.[184]

d. Textile summary

Summarising textile production evidence, the work of the *serikarioi* in Constantinople included dyeing, weaving, and tailoring silks for sale to garment merchants as required. Among textile producers, dyers are most visible to us because the high rate of Jewish participation and the stigma associated the trade meant that the industry is well represented in primary sources. Production of dyestuffs and chemicals used in the process was a major industry in its own right with an extensive international exchange network discussed in many sources. Like other forms of enterprise, quality distinctions and representations, legitimate or otherwise, were inherent to the exchange process.

The work of professional weavers is less well documented in all sources, but seems to have included men and women, as well as slaves. Diverse skills were required with occupations specialised by material and function in a variety of workshop settings. Textile names provide additional details about the production and consumption of silk and other types of cloths in Byzantium. Categories defined in terms of description, material content, and weave structure refer to luxury goods as well as common and utility items.

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[182] *Gre Pak,* Lemerle, 1733-1734.
[183] *Iveron*, 364-371.
[184] *BOE*, Koder, 9.6.442.

4.4 Pattern Analysis

a. Colour

In the Byzantine sources comprising the corpus, the hierarchical arrangement of the court was communicated through fabric characteristics including colour, metal embellishment, and figured pattern woven designs. Garments too played a role in the scheme and have been studied by various scholars.[185] James' analysis of Byzantine colours in art showed that perception was not defined solely by hue, but was also influenced by brilliance and saturation.[186] Some literary works conveyed colour intensity to indicate hierarchy. Psellos described the emperor as being garbed in robes of purple as compared with those of the empress in a less intense shade.[187] James traced colour terminology from early Byzantium into the middle period to show the evolution of perception toward a scheme dominated by specific definition of hues, a development particularly evident from the organisation of complex rituals.[188]

The most comprehensive source of colour information for the middle Byzantine period comes from the *BOC*. Various authors have discussed the validity of this source for specific colour information. James related changes in colour terminology to developments in Byzantine society and culture over time.[189] In her view, the *BOC* is not an accurate guide to the use of colour in court costume because its vocabulary was not standardised.[190]

Having consolidated all 217 instances of textile-related colour mentions from the *BOC* in the corpus database, my analysis shows distinctive patterns in the use of terminology.

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[185] For example, see Parani 2003, Dawson 2002, Piltz 1997.
[186] James 1996, 79.
[187] *Psellos,* Renauld, III, 15, 35; 19, 9; 21, 9; James 1996, 81.
[188] James 1996.
[189] James 1996, 78.
[190] James 1996, 105 n. 87.

Evidently, colour terms were edited for consistency during the reign of Constantine VII, including those used in chapters originally written in prior centuries. Significant discrepancies in colour and other characteristics occur only in chapters 96 and 97, which were added to the compilation later, during the reign of Nikephoros II Phokas. For example, the colour words *kastorion* and *halourgis* appear in chapters 96 and 97 respectively, but do not occur elsewhere in the text.[191]

Contrary to James' perspective, colour terminology for textile items appears to have been used consistently in the *BOC*. Generic references to purple typically applied the word porphyry. Particular garments, ranks, and persons were described specifically in terms of murex-based dyes. Each of the twenty-five references to the purple *sagion* worn by high officials was recorded as *alethinos* for genuine or true purple.[192] Mention of a porphyry *sagion* occurred only once to describe a gold-bordered garment decorated with pearls worn by the emperor.[193] Regular patterns of use are also evident for other murex dye types. The coloured *tablion* applied to the chlamys worn by high officials were described in each of four instances as *oxeon,* a reddish-purple colour.[194] The word *tyrea* appeared only six times in the entire compilation, in each case for the ground colour of a chlamys worn by a patrician.[195] References to white followed a similar pattern. The white chlamys worn by high officials were described as *leukon* in twenty-two instances, and as *aspron* only once.[196] In each of the

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[191] *BOC,* Reiske, I: 96, 438; 97, 440.

[192] *BOC,* Reiske, I: 10, 81-82; 16, 98; 17, 98-100; 17, 104; 18, 109; 30, 167; 30, 169; 45, 231; 46, 236; 47, 241-244; 48, 250-251; 48, 254. II: 7, 539; 11, 549, 15, 575; 15, 587; 15, 590.

[193] *BOC,* Reiske, II, 37, 634.

[194] *BOC,* Reiske, I, 30, 162; II, 15, 575; II, 41, 641. For the meaning of *oxea*, see *Imp Exp*, 169 (B) 108-109.

[195] *BOC,* Reiske, I: 23, 128; 35, 181; 55, 271; 72, 360; II: 41, 641.

[196] *BOC,* Reiske, *leukon*: I: 1, 24; 10,71; 11, 86; 12, 89; 15, 96; 19, 115; 27, 148; 29, 161; 30, 162; 32, 171; 47, 241-242; 51, 260; 264, 284; 68, 303; 86, 391; 91, 416-417; 92, 422; II: 15, 579; 15, 590; 51, 699; 51, 701; *aspron*: II: 30, 630.

three instances that veils were worn by high-ranking women in ceremonies, the colour was *aspron*, not *leukon*.[197]

False purple, *pseudoxea*, was mentioned one time in the *BOC* for the tunics worn by the stewards of the table and again in the *Imperial Expeditions* treatise for belts dispatched to foreigners.[198] While some scholars have interpreted these mentions as evidence of the restriction of murex dyes to high court officials, this interpretation is problematic.[199] As textile researchers and conservators can attest, the composition of particular dyestuffs cannot be perceived by visual inspection.[200] Many compounds were used to achieve various colours and even murex-based dyes contained other substances.[201] Consequently, *pseudoxea* must have referred to some perceptual difference in hue or intensity, in addition to possible differences in chemical composition.

In the early 1800s, a collection of third- to fourth-century 'alchemist' papyri was recovered from late Roman gravesites in central Egypt.[202] The papyri contain a series of recipes to produce imitations of precious metals, valuable dyes, and gemstones. Among the 265 recipes, seventy-five provided instructions for dye, with the majority for purple. Some of the recipe names indicated imitation of expensive murex dye stuffs. Titles included: 'genuine purple', 'Sardian purple', 'Silician purple', 'Tyrian purple', 'bright red purple' and 'good

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[197] *BOC,* Reiske, I: 50, 258; II: 24, 623-624.
[198] *BOC,* Reiske, II: 15, 578; *Imp Exp*, C.244-245.
[199] For discussion of the meaning of the term, see Muthesius 1995b, 293; *Imp Exp*, 169 n. (B) 108-109; 224 n. (C) 244; Jacoby 1991-1992, 483.
[200] For example, see Verhecken 2007.
[201] The literature of historic dye technology is extensive and relies upon chemical analyses to determine chemical components. For a comprehensive synthesis of historical dye stuffs, see Cardon 1999. The journal *Dyes in History and Archaeology* publishes papers presented at annual meetings and represents the most current source of technical information.
[202] Caley and Jensen 2008, 1.

purple'.[203] While this particular collection was unknown in Byzantium, the papyri provide an example of the long-standing tradition of imitative dye arts. Arab and Genizah texts also contain many references to reproductions of expensive dyestuffs for textiles that could be owned and worn by those who could not afford the real article.[204]

b. Metal

Application of gold and other precious metals to textiles was another way to demonstrate hierarchical ordering of the court in the middle Byzantine period. Conspicuous display of precious metals was an obvious way to project wealth and power. James' colour analysis showed the importance attributed to the visual qualities of metal with emphasis on iridescence, shine, and gleam.[205] While her study pertained to mosaics, the same concepts can be applied to textile evidence. Writing about literary and visual representation, Maguire suggested that gold in imperial portraits dematerialised imperial images as a means of associating them with angelic beings and conveying divine qualities.[206] Brubaker noted a similar use of gold in ninth-century manuscript painting to convey light, and by inference, as an expression of divinity.[207] Gold interwoven with silk or applied as embroidery would provide a similar effect.

In his ekphrasis on Hagia Sophia, Paul the Silentary blended perception of light with metal and colour in describing a gold-embroidered altar cloth:

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203 Caley and Jensen 2008, 68-85.
204 See Serjeant 1972, esp. 206-208.
205 James 1996, 115.
206 See Maguire 1989, 228 for panegyric references to the sun and shinning light.
207 Brubaker 1998, 37.

> But by the web, the produce of the foreign worm, changing its coloured threads of many shades. Upon the divine legs is a garment reflecting a golden glow under the rays of rosy-fingered Dawn.[208]

ttaleiates conveyed the aesthetic effect of silk with gleaming metals in his description of the interior of the Nea Church: 'and here they spread out the most luxurious and expensive fabrics while other glittering gold and silver ornaments were affixed along the full length of the route'.[209] While some Byzantine historians did not mention fibre type at all, most referred to gold-embellished textiles.[210]

Silk was an ideal medium to combine with gold because the reflectivity of the materials intensified the radiant appearance. The effect was heightened by colour choice, with either dark, saturated hues for high contrast or the light of bright white. A few mentions suggest that a glaze or polishing agent might have been added to the surface of some cloths to make the material appear more smooth and shiny, and to weight the silk for better drape and body. The eleventh-century *Vita* of St. Nikon reported that after the Jews were expelled from Sparta in about 985, a Jew was brought to the city for the purpose of smoothing and polishing textiles.[211] The *Arabian Nights* referred to a process of glazing a finished piece of embroidered cloth.[212]

As described in the *BOC*, gold was applied to textiles through a variety of means including: weaving, embroidery, gilding, and applique. The terms *chrysoyphes* or

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[208] *Paul Sil*, Bekker, 767-771; tr. from Mango 1986, 88-89.
[209] *Attal,* Brunet, 4, 10-13; tr. from *Attal*, Kaldellis, 19.
[210] For the incidence of gold mentions by author, see the column labeled metal in appendix 4.1
[211] *V. Nikon*, 112-113, 33; 118-121, 35. For tr. of στιλβοῦσθαι τὰ ὑφάσματα as smoothing and polishing, see Jacoby 1991-1992, VII, 455.
[212] *Arabian Nights*, 493; see Serjeant 1972, 199-200.

chrysoyphantos described gold woven into textiles on the loom.[213] Two different types of gold embroidery were mentioned in the text. *Chrysokentetos* referred to gold yarns embroidered to the cloth surface (couched), while *chrysosolenokentetos* was apparently a method of affixing tiny gold tubes to the cloth surface.[214] The literal translation of *chrysophenges* as bright or shinning gold probably meant application of gold leaf to gild textiles.[215]

Other types of gold decorations were sewn to finished garments. *Chrysoperikleistos* was translated by Reiske as gold-bordered, and by Vogt as edged with gold, but Dawson suggested application of tablet woven gold bands.[216] *Chrysoklabos* referred to woven or applied bands running from shoulder to hem.[217] The related terms *chrysosementos* and *chrysa holosementos* have been interpreted as either applique or gold-patterned.[218] Appendix 4.3 provides a summary of the various terms used for gold and incidence of mention in the corpus.

Terminology for the types of gold decorations in the *BOC* followed the same general pattern as the prestige colours discussed above. General references to gold textiles used the word *chrysos*. Specific terms were used to describe garments in terms of a hierarchically ordered scheme. As we have seen, except for the two chapters added during the reign of Nikephoros II Phokas, the consistent use of terminology suggests that the texts were collectively edited for greater consistency in terminology.

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[213] Dawson 2002, 27.
[214] Dawson 2002, 26-27; Woodfin 2012, xxiv-xxvii.
[215] Dawson 2002, 29-30.
[216] *BOC,* Reiske, Comm. 52; *BOC*, Vogt, Comm. I, 30, Dawson 2002, 28-29.
[217] Dawson 2002, 28.
[218] *BOC*, Moffatt, 294 n. 2; Dawson 2002, 28.

The addition of gemstones or pearls to garments was mentioned in the *BOC* on four occasions.[219] The most elaborate garment was a *kolobin*, which was known by the name '*Botrys*,' meaning 'bunch of grapes'.[220] The figured pattern silk garment was embroidered with gold thread and decorated with precious stones and pearls. A scholion to the *Imperial Expedition* treatise referred to a special *chiton* worn by the emperor when he entered the city in an imperial triumph. Known by the name 'rose cluster' (ῥοδόβοτρυς), it was described as *chrysoyphantos* suggesting that the design was woven with silk and gold yarns.[221] The garment was 'covered in pearls set in a criss-cross pattern, and with perfect pearls along the hems'.[222] Several authors including Attaleiates and Choniates mentioned the heavy weight of imperial garments and regalia.[223] Function and practicality limited the extent to which heavy embellishments could be applied to silks, so other means of distinguishing high status textiles had to be devised.

c. Pattern

In addition to colour and precious metals, representational patterns provided a third means of elevating textiles and communicating hierarchy. Textual evidence concerning figured silks shows patterned weaves to be a clear extension of the Byzantine visual sphere. The following discussion of pattern is framed in terms of aesthetic perception and symbolic representation.

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[219] *BOC,* Reiske, I: 10, 80; II: 1, 522; 15, 580; 37, 634.
[220] *BOC,* Reiske, I: 10, 80, 86; ὁ βασιλεὺς κολόβιν τριβλάτιον χρυσοσωληνοκέντητον, διὰ λίθων καὶ μαργάρων ἠμφιεσμένον, ὃ καὶ βότρυς καλεῖται.
[221] *Imp Exp*, C.750-752, 759.
[222] *Imp Exp*, C.750-752.
[223] *Attal,* Brunet, 36, 19, 8-9; *Nik Chon,* Dieten, 273.

1. Aesthetic perception

In her study of colour perception in Byzantium, James documented descriptions from various authors demonstrating aesthetic appreciation for compositions involving variegated colours in forms such as mosaics, marble columns and peacock feathers.[224] In an encomium describing the interior of the Nea Church, the *Vita Basilii* integrated visual references for two different media. The text described the floor mosaics as first appearing 'to be fully spread with rugs woven of silk or of *sidonian* fabrics'.[225]

Several mentions included in the corpus referred to the use of variegated colour, particularly in creating a layered, ambivalent experience. The preface to the *BOC* presented Constantine's prescriptive compilation as:

> Picking flowers from the meadows to set as an incomparable decoration for the imperial splendour, and as if we were setting up in the middle of the palace a radiant and newly cleaned mirror in which are seen what befits the imperial rule and what is worthy of the senatorial body, so that the reins of power will be managed with order and beauty.[226]

As a visual representation of Christ's dual nature for the feast of the Nativity, high officials wore Tyrian purple and yellow-spangled (μηλινοκάθρυπτα) chlamyses.[227] The costume worn by the emperor for the feast of the Ascension represented a similar mingling of colour and pattern with the prescription of a multi-coloured *skaramagion*.[228] Choniates described the experience of the German embassy at the 1196 feast of the Nativity in their visit to the court of Alexios III Angelos:

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[224] James 1996, 125-127.
[225] *V. Basilii*, 84.13.
[226] *BOC,* Reiske, I: Preface, 4; tr. from *BOC*, Moffatt, 4.
[227] *BOC,* Reiske, I: 23, 128; see *BOC*, Moffat, 128 n. 2; *LBG*: (μήλινος + καθρύπτης) mit gelben Spiegeln (Pailletten).
[228] *BOC,* Reiske, I: 37, 188; τριβλατίων σκαραμαγγίων. For a discussion concerning the meaning of *triblattion*, see section 4.4e Polychrome pattern weaves.

> To the Romans who stood among them urging them to gaze upon the full bloom of the precious stones with which the emperor was adorned like a meadow, to pluck the delights of springtime in the middle of winter and enjoy a feast for the eyes.…[229]

According to James, the two qualities that were especially prized in Byzantine colour combinations were contrast and association.[230] John Mauropous related his aesthetic appreciation of colour interpolation in an epigram: ‘beauty is created when two contrasting colours are wonderfully blended together’.[231] The medium of figured textiles required patterns to be woven with contrasting colours at a scale appropriate for the intended viewing distance. For the reception of the foreign ambassadors, the *protospatharioi* wore green and pink *skaramangia* while the *spatharokandidatoi* and the *spatharioi* wore other colour combinations.[232]

2. Symbolic representation

Interpretation of figured patterns described in historical sources requires critical analysis of source evidence to examine intention. Theophanes Confessor conveyed Byzantine suzerainty over Lazica by describing the investiture garments worn in 522 by Tzathios which bore embroidered images of Justin I (518-527).[233] The iconoclasm controversy was clearly referenced in Theophanes’ description of the donation made by Michael I (811-813) on the investiture of his son, Theophylaktos. Michael renewed a set of four curtains of ancient

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[229] *Nik Chon,* Dieten, 477; *Nik Chon,* Magoulias, 262.
[230] James 1996, 122.
[231] *Ioan Maur*, Epigram 100, 51-52.
[232] *BOC,* Reiske, I:15, 576.
[233] *Theoph,* de Boor, 168, 23-26.

manufacture 'splendidly embroidered in gold and purple and decorated with wonderful sacred images'.[234]

Several scholars have investigated patterned silks to explore how textile representation was influenced by iconoclasm.[235] Based on documentary evidence and available technical information about figured silks, Brubaker concluded that the imperial silk workshop remained active during iconoclasm, but that subject matter alone is an insufficient guide for dating.[236] For the middle Byzantine period, Maguire examined the way that costume was used to present the emperor and his court as counterparts to the invisible court of Christ.[237] In his study of liturgical vestments in Byzantium, Woodfin showed the later transformation of Byzantine liturgical dress from its middle Byzantine basis in the imagery and forms of the imperial court.[238]

Figured textiles were visible not only to court officials in imperial ceremonies, but also to the population of Constantinople. Choniates described the imperial triumph declared in 1133 by John II Komnenos to mark the capture of Kastamon. For the occasion, the streets were decorated with gold-embroidered purple cloths as well as woven images of Christ and the saints.[239]

To investigate written descriptions of textile patterns, this analysis considers both incidence of mention as well as the meaning of symbolic representation. The corpus comprises a total of fifty explicitly described figured silks, thirty-nine of which are found in

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[234] *Theoph,* de Boor, 494, 29-31; tr. from *Theoph,* Mango, 678; for re-editing and embellishing earlier iconoclastic sources, see Brubaker and Haldon 2001, 166.
[235] See Maguire 1996, 100-106, 137-145; Muthesius 1997, 2, 60, 68-72, 146.
[236] Brubaker and Haldon 2011, 338-340.
[237] Maguire 1997a, 247-258.
[238] Woodfin 2012.
[239] *Nik Chon,* Dieten, 18, 81-84.

nine chapters of the *BOC*. Of these, twenty-eight appeared in the chapter concerning preparations for reception of foreign ambassadors in May 946.[240] The remaining instances were prescribed for major religious occasions as well as appointments of senior court officials. A total of seventeen different patterns were mentioned with twelve referring to types of animals, nine of which pertained to types of birds with four eagles, three peacocks, one owl, and one partridge. There were also three mentions each for lions and griffons.

Seven pattern mentions referred to combinations that suggest either two or three colour patterns. Two-colour weaves were implied by the white lion silk on an unattested background as well as the quince-yellow spangled pattern on a purple ground mentioned above.[241] Two other instances suggest background colours: the reddish-purple curtains of the *Chrysotriklinos* were reportedly figured with griffins and asses. The dais in the Hall of Justinian was covered with reddish purple '*dinisia*' silks, possibly referring to a Dionysian pattern design.[242]

Some descriptions are accessible to us by analogy to representations found on mosaics and other media.[243] The lion symbolised imperial power, with the griffon and lion-griffon having a similar meaning in a mythical sense as conveyed through Sasanian iconography.[244] Large birds such as peacocks or eagles may have layered imperial and theological concepts.[245] Other described motifs fit with early Byzantine symbolism that associated natural history with Christian art. The plane tree motif on two of the emperor's garments may have been related

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240 *BOC,* Reiske, II: 15.
241 *BOC,* Reiske, I: 23, 128, 13; II: 15, 576, 577-578.
242 *BOC,* Reiske, II: 15, 595, 13; for emendation see *BOC*, Moffatt, 595 n. 2.
243 For discussion of post-iconoclastic portrayal of saints and imagery on textiles, see Maguire 1996, 137-145, esp. 142.
244 Brubaker and Haldon 2001, 91; Maguire 1999b, 192.
245 Maguire 1987, 64-66.

categorically to the larger themes of creation and prosperity.[246] Birds suggest exegetical meaning as symbols for saints and martyrs.[247] The deer motif was a possible reference to baptism and the Eucharist.[248] The fish pattern on the emperor's robe may have symbolised salvation and baptism.[249] Other patterns are more obscure, such as the *thallasa*, described by some translators as a sea or wave motif, possibly in reference to the terrestrial world.[250]

d. Imperial restrictions

Chapter 8 of the *BOE* reflected imperial efforts to maintain the exclusivity of imperial silks. The text defined certain goods as *kekolymena*, meaning forbidden or prohibited. The *serikarioi* were permitted to produce allowed types of silk for sale to the *vestiopratai*. These restrictions were not applicable when the eparch commissioned silks to be woven for purchase by the *idikon*.[251] The implication is that *serikarioi* had the material resources and technical capabilities necessary to produce at least some types of imperial or sub-imperial quality silks when required, but were otherwise prohibited from doing so. The penalty for making prohibited weaves or for selling a slave who knew how to produce such silks to a foreigner was to have a hand cut off.[252] The consequence of delivering silks made abroad to the imperial storeroom (*basilikon kylistareion*) was to be flogged and shaved.

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[246] Maguire 1999a, 246-253.
[247] Maguire 1987, 43.
[248] Maguire 1987, 38-39.
[249] Maguire 1987, 23-24, 30.
[250] For discussion of some interpretations, see *Imp Exp*, 222-223 n. (C) 241. For depictions of ocean themes on textiles, see Maguire 1999a, 245-246.
[251] Note that spelling of *idikon* is from the text, as compared with *eidikon* elsewhere. For discussion of this office, see the section under the heading '2.3 The Imperial Silk Workshop' in chapter 2 above. *BOE*, Koder, 8.2: ἐχτὸς τῶν ἐχόντων ὁρισθῆναι παρὰ τοῦ ἐπάρχου πρὸς χορηγίαν τοῦ ἰδικοῦ.
[252] *BOE*, Koder, 8.11.

The particulars of prohibited goods are listed in paragraphs 8.1, 8.2, and 8.4. These sections are difficult to interpret because the specific terms are not meaningful in literal translation. What is clear is that the regulations referred to categories of attributes. Paragraph 8.4 explicitly prohibited use of muxex dyes for particular types of textiles. Paragraphs 8.1 and 8.2 restricted production of high value silks of one or more colours and in certain colour combinations, including those that gave variegated or multi-coloured effects. Another prohibition pertained either to the size of a finished cloth, or more likely, the scale of a pattern repeat.[253]

A monetary limit was placed on the maximum value of goods produced by the *serikarioi*. As discussed in chapter 2.2, any garment worth more than ten *nomismata* had to be reported to the eparch.[254] The regulation also applied to the guild of the *vestiopratai*.[255] This same market value limit appeared in the *Imperial Expedition* treatise. The *eidikon* was responsible for purchasing various types of garments from the marketplace for values up to ten *nomismata*. Purchased items included Egyptian silks and locally made purple garments. These were intended as gifts for foreigners and for military officials in the event of a rewards presentation at a military camp (*aplekton*).[256]

Regulations pertaining to the *serikarioi* did not mention precious metals in the definition of prohibited goods. Rules for the guild of the *argyropratai*, the sellers of silver, were included in chapter 2 of the *BOE*. Among these, goldsmiths (*chrysochooi*) were prohibited from working in their own houses and had to set up their workshops on the Mese.

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253 *BOE*, Koder, 8.1, 378-379: τὰ δὲ βλαττία κατὰ περσικίων ἤ δισπίθαμα χλανίδια ἐμφανιζέσθωσαν τῷ ἐπάρχῳ....
254 *BOE*, Koder, 8.1, 379-380.
254 *BOE*, Koder, 8.1, 379-380.
255 *BOE*, Koder, 4.2.
256 *Imp Exp*, C.290-293, 510-511.

They were also forbidden purchase of more than one pound of gold bullion at a time.[257] If valuable metals were included in the textiles produced by the *serikarioi*, they would have been easily detected by weight, and subjected to a limit of ten *nomismata*.

References to loom technology and quality of workmanship are evident in chapter 8. Paragraph 8.3 required inspection of silk looms and equipment by certain officials, the *mitotes*, under the authority of the eparch, to ensure that imperial quality goods were not being produced. The inference is that inspectors monitored textiles on workshop looms as they were being woven. Finished goods were also examined by the *boullotes* and required the eparch's seal. Paragraph 8.9 defined the consequences of not having seals affixed to bales of finished cloths.

Regulations for the *serikarioi* defined three qualitative categories of silks: high (*megalozela*), medium (*mesozelon*) and lower quality (*leptozelon*).[258] The *Imperial Expedition* treatise used these same terms to describe the qualities of woven silks produced in the imperial workshop.[259] The *BOE* regulations strictly prohibited production of goods in the high and medium categories, but some lower quality items were allowed. While the full set of attributes involved in grading silks are not clear to us, quality references included yarn type, and possibly diameter as discussed above.[260] Depending upon loom setup and weave structure, fine yarns would have allowed more detailed patterns to be woven with greater design resolution.

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[257] *BOE*, Koder, 2.8, 2.10.
[258] *Imp Exp*, 217-219 n. (C) 226.
[259] *Imp Exp*, C.225-242.
[260] See chapter 4 fn. 95 and 104.

e. Polychrome pattern weaves

Scholars have long puzzled over the meaning of *triblattion* and *diblattion* which appeared only in association with imperial or high prestige silks. In the sources included in the corpus, *triblattion* was specifically named fifteen times and *diblattion* sixteen. In addition to four mentions in the *BOE*,[261] the terms appeared five times in the *BOC*,[262] fifteen in the *Imperial Expeditions* treatise,[263] five in Attaliates' *Diataxis*,[264] once in the *Typikon of Gregory Pakourianos*.[265]

Considering these sources collectively, the terms were used explicitly in conjunction with colour words in eleven instances and in association with figured patterns in thirteen cases. In the *BOC*, *triblattion* was used coincidentally with a description of a chlamys patterned with a plane tree design.[266] This mention was immediately preceded and followed by a number of other descriptions referring to various patterns including griffins, lions, horsemen, and peacocks. The *Imperial Expeditions* treatise included several mentions of *diblattia* decorated with eagles and other imperial symbols in various colour combinations.[267] For the reception of the Saracen ambassadors in the *BOC*, the emperor put on his chlamys with the eagle pattern to receive the guests.[268] The *Diataxis* included a *diblattion* silk with a yellow griffin design.[269] The text also listed a purple *diblattion* curtain with a design of peacocks in conches.[270] For the

261 *BOE*, Koder, 8.1, 8.4.
262 *BOC,* Reiske, I: 10, 80, 11; 37, 188, 21; 48, 255, 7-8; 97, 442, 1-2; II: 15, 581, 2.
263 *Imp Exp*, C.173, 213, 235, 236, 240, 242, 251, 258, 503, 508, 732, 783.
264 *Attal,* Gautier, 1306, 1779, 1887, 1792.
265 *Gre Pak,* Lemerle, 1728.
266 *BOC,* Reiske, II: 15, 581, 1-2.
267 *Imp Exp*, C.240-242, 251-253.
268 *BOC,* Reiske, II: 15, 587, 21.
269 *Attal,* Gautier, 1787-1788.
270 *Attal,* Gautier, 1376-1377.

feast of the Nativity in the *BOC*, some high officials wore chlamyses that were patterned with a design of peacocks in conches.[271]

In his Latin glossary, Du Cange defined *triblattion* as a three-colour cloth and included a description by Peter Damian.[272] In his commentary to the *BOC*, Reiske provided two possible interpretations of the word.[273] In the first, he suggested that the prefix referred to the number of times a silk was placed in a dye bath. Accordingly, a *triblattion* silk would be thrice-dyed, presumably for the purpose of achieving either a deeply saturated cloth or fusion of colours.[274] Muthesius adopted this interpretation in some of her analyses.[275] However, this explanation is inconsistent with dye processing.[276] Submitting a cloth to multiple baths of the same colour treatments would not produce reliably perceivable gradations in colour intensity to support distinct terminology. A combination of different tinctures would still produce a cloth in one shade.[277] Maintaining colour consistency over time would be impractical as even modern processors using chemical dyes in controlled industrial processes experience differences among lots.

Reiske also proposed a literal interpretation of the term with a meaning of a three-coloured textile consistent with Damian's description. Guilland examined the term from this perspective and concluded that *di-* and *triblattion* referred to solid coloured strips of various colours applied to a ground fabric that was usually purple in colour.[278] His analysis did not propose a method of application, nor did he describe the location or physical dimensions of

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[271] *BOC,* Reiske, I: 23, 128, 14.
[272] Du Cange and Carpentier 1733, VI, 1277.
[273] *BOC,* Reiske, *Comm*, 186, 473.
[274] *BOC,* Reiske, 473.
[275] For example Muthesius 2002, 163.
[276] For addition discussion with respect to *blattion* and dyes, see Dawson 2002, 22-26.
[277] Dawson 2002, 24.
[278] Guilland 1949, 339-348.

the strips. To explain the coincidence of *triblattion* with pattern descriptions, he suggested that the designs were embroidered onto the applied colour strips.[279] He concluded by suggesting that the number of bands applied to a garment was an indication of hierarchy and might have designated rank in the manner of clavi.[280] Several scholars including Haldon have adopted Guilland's interpretation.[281]

Despite its general acceptance, Guilland's explanation is problematic from a number of different perspectives. The incidence and context of use indicates that *di*- and *triblattion* occupied a high position in the hierarchy of textiles in imperial use and contributed to the sublime presentation of the emperor and his immediate retinue. Colour banding is among oldest and most common forms of embellishment, in part because it provides a way to recycle used or damaged coloured textiles. In the middle Byzantine period, materials for coloured strips were widely available, required no special processing or skills, and could have been worn by many persons in society. For the purpose of elite differentiation, colour bands would have been inconsistent with use of fine silks, exclusive dyestuffs, and precious metals.

As Guilland pointed out, several different kinds of garments were made from *di*- and *triblattion* such as: chlamys, *skaramagia*, *kolobia*, *divetesia*, and tunics. Furnishings included cushion covers, curtains, altar cloths, hangings, and untailored lengths of cloth. Affixing coloured bands to a variety of different garments would have created a disparate appearance in the otherwise formalised and coherent system of vesture, particularly for items embellished with clavi. A ranking system for furnishings based on coloured bands is difficult to imagine. The idea of affixing coloured strips to unsewn lengths of cloth seems especially questionable

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[279] Guilland 1949, 347.
[280] Guilland 1949, 348.
[281] *Imp Exp*, 205-207 n. (C) 173.

since they might later have been made into tailored items. The corpus contains various references to the use of stripes for decoration on some garments, but only occasionally in association with high officials or the emperor in a ceremonial context.[282] Moreover, no written work included in this corpus attached symbolic or aesthetic importance to the use of colour bands.

Other authors have proposed alterative explanations for the terms. In his analysis of the *Diataxis*, Gautier suggested that the term could mean double or triple layered cloth.[283] This interpretation has been rejected elsewhere, but could be correct if used in reference to complex figured cloths that were woven in distinct layers as in double weaves.[284] Jacoby accepted the three-colour description provided by Damian and suggested a possible connection between *triblattion* and the Arab word *būḳalamūn*.[285] Serjeant defined this term as a silk textile of a Sasanian or Byzantine origin with a peculiar sheen that was manufactured in Egypt.[286] Djāḥīẓ (d. 869) described the cloth as:

> One of the crimson-coloured, Greek kingly textiles, with various lines. Violet is crossed with red and green. They say it changes its colour with the ascendant of the day and the glare of the sun. It is very expensive to buy'.[287]

A telling reference comes from the *Book of Gifts and Rarities*. Included among the elaborate gifts sent by Emperor Romanos I Lekapenos (920-944) to Caliph al-Radi bi-Allah (934-940) in 938 were several brocade cloths:

> One with a design of eagles in two colours, another with a floral [design] in three colours, another also with three-coloured stripes, a red one with coloured foliate design, the design of yet another [represents] trees on a white ground, two with a

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[282] For a possible exception, see *Imp Exp*, C.241-242; 257-258.
[283] *Gre Pak*, Gautier, 96, 97 n. 43, 128 n. 57.
[284] For the definition of double weave, see CIETA 2006, 14.
[285] Jacoby 1991-1992, 458 n. 29.
[286] Serjeant 1972, 143.
[287] *Tidjāra*, 337; tr. from Serjeant 1972, 143.

> design [representing] a hunter set in a roundel on a white ground, two with crouching lions on a yellow ground, two eagles in roundels….[288]

The conclusion from the discussion above is that *triblattion* and *diblattion* were the middle Byzantine terms for imperial quality weft-faced compound weave figured silks. This explanation is consistent with descriptions of aesthetic and symbolic preferences as related through a variety of written sources. This analysis also agrees with accounts of pattern use and colour terminology.[289]

Scholars including Guilland have questioned why only one or two colours at most were named in conjunction with *triblattion* and *diblattion*.[290] In the prescriptive sources that included these terms, the purpose of recording information was for identification rather than comprehensive description. For a bi-colour *diblattion*, either the pattern or the ground was named as discussed above. Polychrome silks with three or more colours would have had a dominant pattern colour and a ground. Reference to other colours would have been cumbersome and unnecessary. For example, a cloth described as *oxea leukotriblatton* would have had a white dominant pattern colour on a red-purple ground.[291]

As noted by Guilland and others, there were clear status distinctions between *triblattion* and *diblattion*. Each of the seven instances of multi-coloured patterned silks worn by the emperor was *triblattion*. Only the cushions provided for the emperor to recline while on campaign were *diblattion*. *Triblattion* silks were awarded only to the *strategos* of important themes. All other senior officials received various qualities of *diblattion* with different imperial symbols according to rank. The implication is that the privilege of wearing

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[288] *Gifts*, 99-101.73.
[289] Dawson 2002, 25-26 concluded that *tri-* and *diblattion* filled a terminology gap in the *BOC* as a technical term for figured pattern weaves.
[290] Guilland 1949, 342.
[291] *Attal,* Gautier, 1790-1792.

variegated colours in a polychrome weave was a prerogative reserved for the emperor and the most senior officials. Patterns for lesser officials were available only in bi-colour silks. The wearing of patterns and particular colours to designate rank was clearly defined by the *BOC*:

> Note that on the actual day of the reception, all those mentioned previously, from the *protospatharioi* down to the lowest ranking person wearing *skaramangion*, stood each according to the colour and pattern of his *skaramangion*, that is, those wearing the pink and green eagles to either side, those wearing the owls and the many-circled eagles, likewise those wearing the wave pattern, and likewise those wearing the white lions. [292]

f. Monochrome pattern weaves

An important type of patterned weave comparable to *tri- and diblattion* in complexity and importance has barely been noticed in the secondary literature.[293] In the *BOC* and the *Imperial Expedition* texts, monochrome pattern silks were identified by the combination of a colour name with the prefix *di-*. Translated literally, *diaspron* meant two whites, a reference to tone-on-tone patterning effect.[294] The *Diataxis* used a similar term, *blattion diphoton,* to describe a silk pectoral garment.[295] With the literal meaning of two shades or tones, the use of *diphoton* to describe a silk cloth suggests a monochrome patterning effect.[296] The designs in monochrome weaves were formed either by incised lines or by the textural contrast of a pattern against a ground. In either case, the effect would have been subtle and elegant. Both

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[292] *BOC,* Reiske, II: 577-578, tr. from *BOC*, Moffatt, 577-578.

[293] For a brief discussion of the term, but without reference to particular sources, see Muthesius 1995b, 296. For the word *diprosopon*, see Koukoules 1948-1952, 2.2, 33. For a discussion monochrome weave structures: Muthesius 1997, 85-93. For explanation of monochrome patterning methods, see Becker 1987, 118-129.

[294] The meaning of *diaspra* was interpreted by Haldon as either a warp and weft of different colours or multiple dye baths. See *Imp Exp*, 217 n. (C) 225.

[295] *Attal,* Gautier, 1798.

[296] *Attal*, Talbot, 371 n. 48.

structures were forerunners of true damask, a modern term which itself alludes to its historical production centre, Damascus.[297]

Additional interpretational evidence is provided by the distribution of colours attested. The sixteen mentions of the weave included: six white, four pink or rose, three yellow, and three blue. Monochrome patterns were often woven in white or light colours because textural contrasts are more easily perceived. The same paragraph of the *BOE* that prohibited the *serikarioi* from weaving *triblattion* and *diblattion* included a third term, *dimoiroxea*, which is conventionally translated as two-thirds purple.[298] Given the naming conventions for monochrome patterns in other sources, the term *dimoiroxea* may have referred to imperial quality 'damask' figured silks.[299]

In the *BOC*, usage context shows that monochrome patterned silks were part of the hierarchical ordering of textiles when all attendants wore white garments. For the most holy festivals – Easter Sunday, Eve of the Epiphany and the Wednesday of mid-Pentecost – only the emperor wore *diaspron* garments. The weave was also used to indicate seniority during the reign of Nikephoros II Phokas. As described in chapter 96, the president of the senate wore a pink 'damask' (*dirodinon*) *chiton* on appointment, and a pink 'damask' *sagion* shot with gold on feast days.[300]

By analogy to the hierarchical distinction between *triblattion* and *diblattion*, monochrome patterned weaves may have been ranked according to the quality of light. One colour patterns in the brightest hues seemed to occupy the most superior position in the

[297] CIETA 2006, 12.
[298] *BOE*, Koder, 8.4; *BOE,* Freshfield, 8.4.
[299] For the sake of brevity, the term used here for monochrome pattern weaves is 'damask' to designate the category of structures discussed in chapter 6.1 Pattern, weave structure and technology.
[300] *BOC,* Reiske, I: 97, 440, 443.

hierarchy associated with the weave. Coloured 'damasks' were included among the goods prepared for the expedition against Crete in 911 as gifts for senior officials.[301] In the *Kletorologion of Philotheos*, doctors wore blue 'damask' *skaramagia*.[302] As with polychrome figured silks, monochrome patterned weaves were used for furnishings as well as garments. Sets of pink 'damask' curtains were hung in the Hippodrome festival held for the Saracen ambassadors.[303]

Among the various characteristics that contributed to the hierarchical ordering of silks, quality is the most difficult to interpret from written sources. In addition to dividing textiles into high, middle, and low categories, the *Imperial Expeditions* treatise referred to subcategories for some items comprising first, second, and third grades. Haldon noted that use of tripartite grading systems was longstanding, with similar references in the *Edict of Diocletian*.[304] Both the *BOC* and the *Imperial Expedition* texts indicate that the qualitative hierarchy of textile gifts was visible and understood by the giver and receiver of as well as the broader community of observers.[305] The limitation of textual evidence is that we do not know the specific textile characteristics that distinguished imperial and non-imperial categories of goods, nor do we understand the basis for ranking within each category. Nevertheless, we can surmise that this 'qualitative hierarchy' resulted in tangible differences in workshop practices by textile type.

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[301] *BOC,* Reiske, II: 44, 661.
[302] *Listes*, 183.20.
[303] *BOC,* Reiske, I: 15, 589.
[304] *Imp Exp*, 224 n. (C) 243-244.
[305] For example *BOC,* Reiske, I: 44, 227-230; II: 18, 607; *Imp Exp*, C.503-511.

g. Pattern summary

The properties of silk made it a highly adaptable medium for expression of imperial concepts. The high dye receptivity of the material provided a means to convey rank through colour with the capacity for nuanced presentation of information. Like metal, silk reflects light to display a shimmering, radiant presence. Combining colour with gold intensified the visual display of wealth and divine qualities. While gold was applied to silk garments and furnishings through every available means, woven patterns provided another device to communicate hierarchy.

Pattern weaving technology provided a means of differentiating imperial silks given the long-standing problem of imitative colour and metal use. Woven patterns coincided with aesthetic preferences for variegated colours. Use of textiles for symbolic representation in garments provided a powerful means of projecting information with the advantages of portability and intimate association with the wearer. By the middle Byzantine period, textile prerogative was defined by a combination of elements that were modulated according to need. Information was conveyed through the interaction of components including garment type, material composition, precious metals, applied embellishments, and colour combinations.

Description of particular prohibitions provides the best available definition of the properties that constituted imperial quality silks. As interpreted in this section, these included particular dyestuffs, colour combinations, pattern scale, yarn size, quality attributes, and monetary value. Critical analysis clarifies the long-debated meaning of *di-* and *triblattion* as bi-colour and polychrome weft-faced compound weave figured pattern silks. Although they had less apparent visual impact, the use of *diaspron* pattern weaves was means of designating rank on occasions when the ceremonial rite called for white garments.

4.5 Patterned silks in regional exchange

A number of different kinds of patterned silk textiles, known to us by both name and description, were extensively documented in written sources. The quantity of information about luxury textiles in Islamic and Genizah texts is extensive. The following summary conveys a perspective on the variety and types of weaves explicitly associated with Byzantium. Most of the textiles described below have been translated as brocade, which is a general word for any richly figured textile, and by extension, is applied to any textile with a woven pattern.[306] An important qualification is that the term is non-specific and does not refer to a particular weave structure, so is not used in technical textile analyses.

a. Sidonia and sendal

Sidonian fabrics are mentioned twice in the *Vita Basilii*. In both instances, the term referred to variegated colours.[307] The meaning of the term is ambiguous and reflects long use. In the *Iliad*, Homer referred to the cloth brought from Sidon by Paris.[308] It appeared in the first-century *Periplus Mari Erythraei* as a term for linen, but was used elsewhere as a term for fine cotton garments.[309] The *Vita Basilii* provided a rare and informative view of changing textile terminology in a brief digression: 'richly variegated *sidonian* fabrics that are now called *sendais* their name seemingly having been corrupted through the ignorance of the many'.[310] In his analysis of the text, Runciman did not consider the possibility that *sidonia*

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[306] CIETA 2006, 8. The term βορκαδίων was used twice in the *Imperial Expedition* treatise B. 109 and C.491. The terms was translated by Haldon as brocade, but he qualified this interpretation in his notes. See *Imp Exp*, 197 n. (C) 124.
[307] *V. Basilii*, 74.31-37; 84.13.
[308] *Iliad*, 6.288-295. See Scheid and Svenbro 1996, 18, 177 n. 41.
[309] *Periplus*, 249, 292-293; Jacoby 2004, 459, 32.
[310] *V. Basilii*, 74.31-37. For a summary of literature discussing *sendes* and *sidonia*, see *Imp Exp*, 214 n. (C) 222; 215 n. (C) 222.

referred to silk, but its confusion with *sendal* suggests that it did.[311] According to Jacoby, σενδές was derived from the Arabic word *sundus*, which appeared in several literary works.[312] Serjeant defined the term as a generic word for silk cloths, sheets, or hangings.[313] The word was also used in some works to describe a kind of green brocade.[314]

Although the word *sendal* was used nine times in the *BOC*, it appeared only in the chapter describing preparations for the reception of ambassadors.[315] Among these, two mentions referred to *sendal* pennons (banners) woven with gold carried by the *hetaireia*, a unit of the emperor's bodyguard. Other pennons were described as all gold with gold stripes.[316] In seven instances, lengths of *sendal* were cited as decorations. The cloths were used to make an arcade in the Magnaura and embellished with polished bronze chains.[317] The eparch was responsible for fitting out particular areas with cloths including *blattia* and *sendal*.[318]

b. Dībādj

Dībādj is one of the most common textile names found in Islamic sources, and was mentioned in nearly every reference to luxury textiles, particularly for products of Byzantium. In a reference book of terms, al-Muṭarrizī (1144-1213) defined *dībādj* as a cloth with a warp and weft of *ibrīsm*-silk.[319] Usage patterns suggest that the word was a general term for

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[311] Runciman 1940, 426-427.
[312] Jacoby 1991-1992, 459 n.34.
[313] Serjeant 1972, 159 n. 29
[314] Serjeant 1972, 159 n. 29.
[315] *BOC,* Reiske, II: 15, 571-573, 576-577.
[316] *BOC,* Reiske, II: 15, 577, 3-4; see *BOC*, Moffatt, 577 n. 1.
[317] *BOC,* Reiske, II: 15, 571, 9, 13, 17.
[318] *BOC,* Reiske, II: 15, 572, 9, 16, 21.
[319] *Muṭarrizī*, I.173; tr. from Serjeant 1972, 41 n. 9.

brocade. *Dībādj* appeared in such a wide variety of contexts and uses that more specific interpretation is not possible.

In writing about references to silk in Genizah letters, Gil observed that *dībādj* was the term used most frequently, providing another perspective on broad availability and use.[320] He pointed to the origin of the term in Arabic as a Persian loan word with the root meaning to shine or glare.[321] Collective consideration of the sources suggest that *dībādj* was used in a generic sense to refer to a variety of cloths that shared the common feature of pattern woven designs, but were not necessarily complex representational figures.

Among Islamic sources, many cities are mentioned as locations notable for their manufacture of *dībādj*, including Baghdad, Basra, Tustar, and many others in Persian provinces.[322] In his ca. 1037 expository text on the specialties of different lands, Tha'ālibī referred to Byzantine brocades as a standard for comparison with products manufactured elsewhere: 'Tusta, which produces splendidly-embroidered and costly brocades, worthy to be mentioned in the same breath as those of *Rūm*'.[323] Comparing the abundance of specialties found in India with those of Byzantium, he observed: 'the Greeks only have the following: *dībādj,* gum mastic, *terra sigillata*, and *sundus* which is called *buzyūn*, and various different kinds of garments'.[324]

Dībādj was conspicuous in gift exchanges and displays of wealth and power. Among the 106 accounts of gifts recorded in the *Book of Gifts and Rarities* at least 20% specifically mentioned valuable gifts involving *dībādj*. These are described as brocade covers with

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[320] Gil 2002, 32.
[321] Gil 2002, 32.
[322] For various examples, see Serjeant 1972, 245.
[323] *Tha'ālibī,* Bosworth, 126. For a reading of brocade rather than satin, see Serjeant 1972, 43.
[324] *Tha'ālibī,* de Jong, 125; tr. from Serjeant 1972, 217 and *Tha'ālibī,* Bosworth, 139.

designs, multi-coloured cloths, velvet, thin brocade with woven animal figures, and cloths with embroidered borders.[325] In ca. 912, Miskawayh reported that the mother of the Abbasid Caliph al-Muḳtadir (908-932) had many boxes containing embroideries and the brocade of *Rūm* and Tustar, heavily adorned with gold, carpets of leather, striped silks, and brocade.[326] In 917, the Caliph received the Byzantine ambassador in his palace. A splendid display was arranged to impress the envoy:

> The number of gold curtains of *dībādj* with magnificent gold embroideries, with figures of cups, elephants, horses, camels, wild beasts, and birds, and large Baṣinnā, Armenian, Wāsiṭ, and *bahnasā* curtains….[327]

c. Buzyūn

According to Lombard, the Arabic term *buzyūn* was derived from the Greek *bussinon* or *bussion* to describe a kind of Byzantine silk brocade.[328] Alternatively, Goitein placed the derivation of the name from a city by the name Buziyān located near Herat in north-eastern Iran.[329] The cloth was included in a list of special products described by Djāḥīẓ:

> The best and most expensive drapery is the crimson Armenian goat hair kind with a double woof, then the striped silk, then the brocade of the *khusrawani* (royal) *Rūmī* manufacture, then the *khazz*-silk brocaded like Maisani, then *buzyūn*-silk; whatsoever of those varieties is woven with gold is finer and fetches a higher price. All those kinds are sometimes woven with gold, except the Armenian and Maisani, and *buzyūn* silk.[330]

As compared with *dībādj*, mentions of *buzyūn* are infrequent and used only in association with brocades from Byzantium or Armenia. Ibn al-Fakīh, a ninth-century geographer, cited *rūmī buzyūn* brocade among a list of special products obtained only from

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[325] *Gifts*, 99-102.73-74.
[326] *Miskawayh*, I, 244; tr. from Serjeant 1972, 42.
[327] Salmon 1904, 52, French tr.: 135; English tr. from Serjeant 1972, 22.
[328] Lombard 1978, 244-245.
[329] Goitein 1977, 85 n. 37.
[330] *Tidjāra*; tr. from Serjeant 1972, 60.

certain lands through merchant ventures.[331] Writing in the mid-tenth century, the geographer al-Iṣṭakhrī mentioned *buzyūn* among the products of Armenia including kermes dyestuffs, carpets and other kinds of cloths.[332] Ibn Ḥawḳal, his direct continuator, expanded on the products of Armenia to say 'From it much *buzyūn* brocade is brought; there are many varieties similar to it in *Rūm*, though it is itself exported.[333]

The context of mentions and frequent association with other high value and exclusive items suggests that *buzyūn* was a costly product available only to elite members of society. However, there were also mentions of the material in the Cairo Genizah in ways that indicate that the material was imitated and cheaply reproduced for purchase by people with more modest incomes.[334] In a Karaite *ketubbā* dated 1028, a modest trousseau list included a sofa of *buzyūn* with a value of only 2 dinars, equivalent to the cost of a dress or robe.[335] Another marriage contract written about 1090 included a *buzyūn* mattress with cushions that was also valued at 2 dinars.[336]

d. Sigillatos

The textile type known in Greek as *sigillatos* has a long and complicated history, much debated by textile scholars, and serves as an example of the evolving nature of textile terminology.[337] Munro's comprehensive analysis traces the meaning of the Greco-Roman term as either a circular robe or a woolen or linen textile decorated by seals or rings.[338] The word entered Persian and Arab lexicons as *siqlātūn* where it evolved to mean a fine cloth of

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[331] *al-Faḳīh*, V, 50; tr. from Serjeant 1972, 202, 213; Lombard 1978, 244.
[332] *Iṣṭakhrī*, 188; tr. from Serjeant 1972, 64.
[333] *Ḥawḳal*, 244; tr. from Serjeant 1972, 65.
[334] Goitein 1967-1993, IV, 452 n. 46.
[335] Goitein 1967-1993, IV, 305, 316; Goitein 1977, 81-86; ULC Add. 3430.
[336] Goitein 1967-1993, IV, 452 n. 46; ENA 2727, f. 8,1. 18.
[337] See Koutava-Delivoria 1990.
[338] Munro 1983, 22.

wool or linen, and later silk.[339] In addition to the large quantity of brocades mentioned above, Emperor Romanos I Lekapenos' gift to Caliph al-Radi bi-allah included many *siqlātūn* cloths.[340]

In the textile trade of the time, it became known as an ornately decorated heavy silk interwoven with threads of gold.[341] An administrative text written in Baghdad in the early eleventh century stated that the weight of gold and silk should be equal in the manufacture of *siqlātūn*.[342] It was also mentioned in several Geniza letters including a *ketubbā* written in Tyre in 1054.[343] It was reportedly produced in a number of different centres including Tabriz, Baghdad, Antioch, Armenia, and Spain, but was also described in debased forms as well.[344]

e. Geographic references

In addition to naming specific textile types, some mentions in Arab sources include specific geographic information. Mas'ūdī (ca. 896-956) included numerous references to trade with Byzantium in his history, *Muruj al-Dhahab*. Discussing the Black Sea trade, he described Trebizond as a place 'where every year several markets frequented by a large number of Muslim merchants, Roman, Armenians, and others, besides those who come from the countries of Circassia'.[345] Describing trade in silk, al-Iṣṭakhrī wrote:

> They have a place of entry into Byzantium, known as *Tarabazunda* (Trebizond), where merchants assemble to enter the land of *Rūm* for the purpose of trading. All

[339] Munro 1983, 20-21.
[340] *Gifts*, 99-101.73; see chapter 4 fn. 288.
[341] For the origin of the word, see Lombard 1978, 242.
[342] Cahen 1951, 27.
[343] Gil 2002, 35, K 128.
[344] Lombard 1978, 243.
[345] *Mas'ūdī,* Barbier de Meynard, II, 3.

> the brocade, *buzyūn* brocade, and garments of *Rūm* which come to these parts, are from Trebizond.[346]

Mas'ūdī also relayed a complicated story (ca. 944) concerning a plot to kidnap a Byzantine patrician. The account conveyed first-hand observations of shipping traffic in the Bosphoros.[347] The story revolved around the valuable Islamic textiles ordered by a patrician and allegedly delivered for his inspection.[348] Compiled in 982/3, the anonymous geographic work known as the *Hudūd al-Alam* reported that Byzantium 'produces in great quantities brocades (*jāma-yi dībā*), *sundus* textiles (of silk), *maysānī*, carpets, stockings, and valuable trouser-cords'.[349]

f. Patterned silks in regional exchange summary

As demonstrated above, a wide variety of luxury textiles are discussed in the sources considered in this work. The general picture is one of a cosmopolitan and diverse textile economy with Byzantine producers and consumers actively participating in a dynamic regional trade network. Representational figured silks were only one of a number of valuable textile types in the empire and elsewhere. The frequent mention of Byzantine 'brocades', both as exported products as well as those made elsewhere in the same style, demonstrate that patterned silks had a distinctive and recognisable identity. Although we lack precise descriptions, Byzantine figured silks appear to have been influential in the material cultures of neighbouring countries.

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346 *Iṣṭakhrī*, I, 152; tr. from Serjeant 1972, 63.
347 *Mas'ūdī*, Lunde, 320-324.
348 *Mas'ūdī*, Lunde, 322-323.
349 *Hudūd*, 41, 2.

4.6 End Use and Consumer Analysis

a. Incidence of silk and precious metals

Textile mentions in Islamic literary sources convey the impression that silk was widely available and accessible to persons of means, but provide limited objective data. Marriage contracts from the Cairo Genizah represent a complementary source of information, and are specific enough to discern patterns about the role of textiles in domestic material culture. Goitein's study of contracts divided reported wealth into seven economic classes ranging from destitute to wealthy.[350] His work showed that about 70% of trousseau lists fell into categories comprising modest and middle class families. I applied this same approach to analysis of the contracts included in Olszowy-Schlanger's compilation of Kararite marriage documents.[351] Among these, twenty-two documents, comprising a total of 217 valued textile objects, contain sufficient detail for analysis.[352] From these data, it is possible to assess the incidence of various types of textiles.

In the Karaite documents, silk, alone or in combination with other fibres, appeared in seventeen trousseau lists, representing approximately 30% of all listed items, including those for which no fibre type was specified. Segregating items by category, the percentage of silk found in household goods was slightly higher than for garments at about 35%, mainly because

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[350] Goitein 1967-1993, IV n. 34, 449. See volume III, 363-422, especially the summary, 418-422.

[351] Olszowy-Schlanger 1998, 15-18. The editor identified early Karaism as a distinct Jewish movement in which written traditions were dominant, as compared with Rabbinic acceptance of oral as well as written transmissions.

[352] Olszowy-Schlanger 1998. The following documents are included in this analysis: Nos. 2: TS 20. 47r; 15: TS 6 Ja 2; 20: TS 12. 621; 21: TS 12. 658; 23: TS 12. 715 and BODL. MA HEB. A. 3. 34; 25: TS 13 J 37. 11; 27: TS 16. 80; 28: TS 16. 236; 29: TS 20. 2; 30: TS 20. 156; 31: TS 24.7; 32: TS 24. 13; 33: TS 24, 45 and TS NS J 86; 36: TS AS 155. 433; 37: TS NS 320. 34 a, b; 38: TS NS 323. 35, TS NS 320. 76a, b, and TS 12. 535; 39: CUL Add. 3430; 40: BODL. MS HEB.a 3. 44; 42: BODL. MS HEB.b. 12. 31; 44: ENA NS 3. 23 and ENA NS 3. 27; 46: II FIRK. HEB. A. 717 r; 56: BODL. MS HEB. A. 3. 42.

furnishings were more costly than garments. These data suggest that silk was affordable, at least in limited quantities, by a majority of families, including those in modest income groups. As expected, the proportion of articles containing silk increased with family wealth.

Approximately 10% of all listed items included some gold, incorporated by weaving, embroidery, or gilding. Among the twenty inventories analysed, seventeen contained at least one golden textile, with the two wealthiest brides each owning four metallic articles. As was the case with silk, the distribution between garments and furnishings was roughly in proportion to their incidence on the lists. Most gold textiles in household use were for *ṭabarī*, a heavy silk fabric woven with gold yarn, commonly used for soft furnishings such as couches and pillows. Originally manufactured in Tabaristan in northern Iran, *ṭabarī* had once been a prerogative of the Sassanian kings of Persia, then the caliphal court of Baghdad.[353] It subsequently became popular everywhere and was widely imitated at various production centres throughout the region.[354]

A final observation pertains to the incremental value associated with the inclusion of gold yarn in textile products. Among the set of trousseau lists discussed above, there were two instances of tunics interwoven with metal yarns. In an early eleventh-century list, a plain tunic with golden thread was recorded at twenty dinars.[355] By comparison, the average price for a new tunic without gold was between one to five dinars. A trousseau dated to the late 1080s or 1090s included a second-hand, gold-threaded tunic that was valued at five dinars.[356] In other contracts, unembellished, used tunics were valued at one dinar or less. These two instances suggest a premium for gold that was many times the basic value of the garment and may have

[353] Goitein 1967-1993, IV, 109.
[354] Goitein 1967-1993, IV, 109.
[355] Olszowy-Schlanger 1998, ENA NS 3. 23; ENA NS 3. 27.
[356] Olszowy-Schlanger 1998, TS 24.45 and TS NS J 86.

been determined by weight. Goitein observed a similar ‘gold premium’ in his analysis of a trousseau list dated 1156. In this list, most robes were recorded in the range of three to six dinars, but a garment with gold threads was valued at twenty dinars.[357]

b. Geographic names and brand preference

Byzantine sources referred to a number of textiles and garments by geographic name only, presumably the place of manufacture. The *BOC* mentioned Saracen and Egyptian textiles as well as *persika* meaning Persian imported or styled cloth.[358] Both Islamic and Genizah sources mentioned *rūmī* textiles and garments in several instances.[359] As described in the *BOE,* the imported silks sold by the *prandiopratai*, included textiles imported from Syria, Seleucia, Baghdad, and elsewhere.[360] The association of Islamic workshops with these imported goods is evident through the term used for silk. Rather than referring to *serika* or *blattia*, paragraph 5.1 of the *prandiopratai* regulations carried over the Arabic word *ḥarīr* transliterated into Greek as *chareria* (χαρέρια).[361]

For most geographic names, we have limited descriptive information, making their meaning obscure. One way to gain additional information about textiles is to interpret them from a consumer perspective. Certain named textiles appeared with such frequency that a hierarchy of preferences is evident. The conspicuous use of certain words and their association with desired attributes and qualities suggests that some textile names were in effect ‘brands’. This is not to imply promotional efforts on the part of producers in a modern

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[357] Goitein 1976, 221-224.
[358] *BOC,* Reiske, II.15.574.5; Du Cange 1943, s.v. περσίκιον; *BOC,* Reiske, *Comm*. 386; Guilland 1949, 348-350; for interpretation as pockets or pouches, see *Imp Exp*, 225 n. (C) 252.
[359] See Serjeant 1972, 258; Goitein 1967-1993, VI, 98.
[360] *BOE*, Koder, 5.1.265-266, 272-273; 5.2.271.
[361] *BOE*, Nicole, 29 n. 9.

sense. My analysis shows how examining textiles from a consumer perspective provides a means of assessing social attitudes from written inventories.

Comparative analysis suggests conscious recognition of ‘brand’ identity on the part of the consumer. Trousseau lists and Islamic sources included many mentions of *ṭabarī* as noted above. Among the marriage contracts in Olszowy-Schlanger’s compilation, no. 2 mentioned *ṭabarī* textiles from Ramle, in Palestine, while no. 25 emphasised genuine *ṭabarī* from Tabaristan.[362] This example suggests authenticity and value associated with a particular production centre.

Expanding on the association of product identity with production place, Arab literary sources include many mentions describing migration of textile production for reasons including imitation and outright fakery. In the tenth century, Makdisi reported that in Wasit, southeast of Baghdad, curtains were made with the words ‘manufacture of Basinna’ written on them. Basinna was a famous production centre located east of Wasit, in the province of Khuzistan.[363] In another mention, Tustar, to the northwest of Basra, was reported to have been especially renown for its ‘*rūmī*’ brocades.[364] For the town of Susan in Khuzistan, we hear that ‘there are garments resembling those of Baghdad. They are taken to Baghdad, and exposed for sale as Baghdad cloth’.[365]

Trousseau lists included many mentions of the valuable *dabīḳī* linens for which Egypt was famous.[366] *Dabīḳī* items were generally valued at twice the amount of like articles made from unnamed types of linen. Among various linens, only *dabīḳī* cloths were reported as

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[362] Olszowy-Schlanger 1998: no. 2: TS 20.47r, 279-282; no. 25: TS 13 J 37.11, 340-342.
[363] *Muqaddasī*, 416; tr. from Serjeant 1972, 36.
[364] *Muqaddasī*, 416; tr. from Serjeant 1972, 43.
[365] *Iṣṭakhrī*, 93; tr. from Serjeant 1972, 47.
[366] Olszowy-Schlanger 1998. See the documents listed in chapter 4 fn. 352.

having applied decorations, such as gilding and silk embroidery. A handful of surviving inscribed linens indicates that a production centre named Dabīḳ existed in earlier centuries. However, by the time the Genizah contracts were written, the site had become obscure.[367] The conclusion is that *dabīḳī* linens lost their specific geographic reference over time, but the 'brand' name carried a reputation for quality and prestige.

In the trousseau lists, *rūmī*-designated goods fell into two distinct categories. Prominent among women's garments were mentions of *rūmī mandīl*, apparently a kind of multi-purpose garment that could serve as a shawl, scarf, or veil. Although some scholars have interpreted the garment as having been imported from Byzantium, the evidence is unclear.[368] Since most *mandīl* seem to have been made of linen, not silk or brocade, *rūmī mandīl* may have referred to a type of garment or fashion rather than a specific type of textile. A Byzantine association with the *rūmī* designation is more evident for household goods, especially furniture coverings and curtains. In these instances, *rūmī* was almost always paired with the word *dībādj*. However, the trousseau lists are vague, so we cannot assume that goods included representational figured patterns.

c. End use summary

In summary, this analysis provides an example of how evidence from various types of sources can be integrated to provide insights into historical cross-cultural exchange. By aggregating data from various sources, we gain a more coherent view of textiles, not only in terms of frequency of mention, but also in the diversity of names and terminologies applied. In particular, geographic-based trade names demonstrate a circulation of textile goods that was remarkable in both its diversity and range. The concept of 'brand' helps to convey

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[367] Goitein 1967-1993, IV, 165-166; Lombard 1978, 160.
[368] Stillman 1972, 145-163.

contemporary attitudes and preferences regarding textile-based goods. We obtain a view of what constitutes appropriate use for certain materials and see evidence of informed consumption. Even in non-elite use, valuable textiles projected status and a desired standard of living.

4.7 Conclusion

In reviewing this corpus of source material, a modern reader becomes aware that textile descriptions communicate a subtle quality in the form of shared social experience. By consolidating textile mentions, we obtain a striking view of widespread awareness of various qualities and close familiarity with different materials. We see a high degree of discrimination among textile types with a refined sense of differences. References to common images are evident in the terminology associated with textiles. Through language, we see a rich environment of cloth in the material culture of the time.

a. Silk and society

Considered collectively, textile mentions provide a body of evidence to examine the role and social importance of silk in the material culture of the middle Byzantine period. In contrast to the lingering perception that silk was an imperial monopoly, the material appears to have been widely available in Constantinople as well as in provincial towns. As compared to other fibres, silk was considered to be relatively luxurious, but was only one factor contributing to the value of a particular textile. Equally, it never became common enough to displace traditional indigenous fibres. While silk remained a luxury fibre on a comparative basis, not all luxury items contained silk and not all silk-based textiles were high value goods. Various types of low quality silk products were produced in response to consumer demand.

The evidence for silk production processes from fibre through to finished goods demonstrates the role of imitation in the spread of the material's consumption and production as a long-term social process. As described in chapter 2.1, in early Byzantium, imperial prerogative concerning silk was defined in association with purple murex dyes. The evidence presented in this chapter show that exclusive luxury goods spawned reproductions and cheaper forms of material. Violation of sumptuary and production laws for silk described in both chapters 2 and 4, as well as the examples of fraud and trickery involving textiles, were all indications of imitative production and use.

b. Silk and hierarchy

Continuing this dynamic, the desire for elite differentiation spurred new materials and methods. Production of complex figured silks woven on specialised looms in the imperial silk workshop provided a means of limiting imitative products. *Triblattion*, *diblattion* and high quality 'damask' weaves were technical and institutional adaptations to elevate precious silks as an imperial resource. The hierarchy of goods produced in the imperial workshop provides a perspective on the administrative infrastructure necessary to support production processes. The *serikarioi* regulations in the *BOE* demonstrate imperial efforts to prevent reproductions. While regulations may have curbed certain products in the short term, patterned silks were extensively imitated and traded throughout the region. As the many references to figured silks in Islamic and Genizah sources show, Byzantine-style figured silks, genuine or not, had a distinctive identity that was desired by neighbouring cultures.

Despite the popularity of patterned silks, woven designs alone did not represent imperial silks. Primary sources indicate that a combination of independent decorative choices involving colour, metal use, and patterning were part of an evolving Byzantine aesthetic that formed a powerful medium for display. Representational patterns provided a means to integrate colours systematically and harmoniously, as well as to communicate symbolic meaning and convey rank. The combination of various garment types with colour, metal, applied embellishments, and pattern supplied an extensive palette for ceremonial displays that was modulated according to purpose.

c. Silk and regional exchange

Even in non-elite use, textiles projected status and a desired standard of living. The prominence of dyers in Byzantine society suggests that coloured textiles were common in daily life. Patterned weaves, especially silk, were part of the relative hierarchy of textiles that included, but was not exclusive to, the luxury products enjoyed by elite members of society. Byzantine, Islamic, and Genizah sources all show that figured patterns were highly visible in the material cultures of the time. Analysis of Genizah marriage contracts suggests that garments and cloth household furnishings were an important part of family property. The most highly regarded textiles included precious metals. Silk was only one of several desirable attributes that encompassed colour, fibre type, embellishment, and finishing details. Reputed production location had a large effect on perceived value.

The evidence presented above demonstrates that silk was a regional material that transcended political, religious, and cultural boundaries in both production and use. By the tenth or eleventh centuries, silk fibre production was widely dispersed in the region, from Persia to Spain, with a large number of production centres producing fibre with different characteristics. Significant qualitative differences existed among the many types of silk, with wide price variation among different grades. The evidence also shows that fibre type and relative grade were determinants of textile quality.

The second part of this dissertation examines the material characteristics of figured silks attributed to various Mediterranean and Near East workshops. The intention is to establish an evidentiary basis to integrate textual evidence with surviving silk fragments according to a common framework.

PART II: CHAPTER 5 - TECHNICAL ANALYSIS OF TEXTILE REMAINS

Having established a framework for analysis of silk from textual sources in the first half of this work, the following chapters provide a complementary perspective on surviving patterned textile fragments attributed to Mediterranean and Near East workshops between ca. 600-1300. The focus of this investigation is a specific category of textiles known as weft-faced compound weave figured silks. Surviving evidence shows that this structure was the dominant method of patterning silk textiles at production centres throughout the region.[1]

Parallel to the framework applied to written sources, chapters 5 through 7 examine figured silk fragments. This chapter describes how research approaches have been shaped by recovery and formation of collections. During the past century, various methods have been applied to study the material and devise a framework for attribution. Chapter 6 defines a new research methodology based on characterisation of silks using high-resolution digital images and software tools to aid in objective analysis. Chapter 7 examines data collected according to the defined protocol and presents research findings.

5.1 Survival Contexts

Thousands of weft-faced compound weave figured silk fragments attributed to Mediterranean and Near East workshops are housed in museums, private collections, and religious institutions, mainly in Europe and North America. Most figured silks were found in one of two contexts: reliquaries and shrines in European churches, and archaeological excavations of cemeteries in the Near East. Textiles from these contexts vary widely in terms of their cultural and historical circumstances of survival. Factors that affect present conditions

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[1] See chapter 7 for a discussion of patterning methods.

include environmental exposures, post-discovery handling of materials, and exchange through a network of dealers and collectors.

a. Silk from European shrines

Some of the most impressive figured silks have come down to us from the shrines of saints and elite tombs in European churches. Both the quality and quantity of these materials can be attributed to two factors: the high value accorded to imported silks in the history of Europe, and rituals associated with the relics of saints. In Christian Europe, imported silks were highly valued.[2]

The westward flow of silk as diplomatic gifts was well documented in primary sources. The *Liber pontificalis* recorded donations of a large number of precious silks to religious institutions where they were used for various purposes such as wrappings for relics, vestments, hangings, furnishings, metalwork linings, and book-bindings.[3] Patrons included rulers and their families, high ecclesiastics, and wealthy laymen.[4] Donation records survive in some institutions such as Sens Cathedral. In 1897 Chartraire published an inventory of the Sens Cathedral Treasury which included endowments by Charlemagne.[5] The quantity and diversity of surviving silks and their widespread distribution across many religious institutions indicates that patrons acquired them through various means including trade and as spoils of war.

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[2] Muthesius 1982, 10. For compendia of European sources pertaining to valuable textiles, see Michel 1852, Parts I and II, 6-87; Sabbe 1935a; Sabbe 1935b.

[3] For example *LP*, Davis 8th, 24, 27-28, 44-45, 81, 143-146, 153-156, 180-182, 193-200, 219-220, 223-230, 236; *LP*, Davis 9th, 14, 20-24, 54, 58-59, 62, 65. See Brubaker and Haldon 2001, 80-108; Martiniani-Reber 1999.

[4] For a summary of inventory records pertaining to donations of valuable silks, see Muthesius 1982, 329-336.

[5] Chartraire 1897, I-IV. For other references to Charlemange, see chapters 1.2 and 2.3.

In medieval Christian Europe, the cult of saints refers to the rituals and institutions surrounding the posthumous commemoration and veneration of a recognised holy person.[6] Saints' physical remains were translated from extramural sites to shrines in churches as focal points for public veneration and pilgrimage. The exceptional social value attributed to silk was demonstrated by its use to wrap and adorn saintly relics encased in special crypts, sarcophagi, or reliquaries located in chapels and altars. Over time, institutions with important relic groups became major pilgrimage centres.

In addition to recognised holy persons, the bodies of elite persons in society, including princely family members and high church officials, were often robed in fine silk garments and placed in crypts located in religious institutions. In times of political and social unrest, these shrines and tombs were subjected to widespread destruction. Over the centuries, the contents of many were lost to war, theft, natural disasters, neglect, and dissolution.

Given silk's relative fragility and organic composition, survival of a reasonably large body of material seems miraculous. Conservation experience shows that the seasonal, humid climate of Europe is a poor preservation environment.[7] Over the centuries, silks exposed to normal ambient conditions simply turned to dust. Textiles placed in subterranean sealed crypts and airless chambers were protected from a wide range of exposures leading to decomposition. A stable micro-environment protected tomb contents from the deleterious effects of light as well as fluctuating temperature and humidity levels.[8] In such conditions,

[6] For definition and discussion of the cult of saints, see Brown 1981; Hayward and Howard-Johnston 1999. For an in-depth study of a shrine's history, see Bonner, Rollason, et al. 1989.
[7] Wild 1988, 12-13.
[8] Wild 1988, 12-13; Wild 1990, 3-4. For a discussion of the specific factors involved in textile damage, see Cooke 1990, 9.

protein-based fibres such as silk are less susceptible to biological antagonists than cellulose materials like linen.[9]

The circumstances through which ancient silks were removed from shrines and eventually accessioned into public collections are a product of a complex set of conditions, events, and broad social changes. In his summary of luxury textiles found in religious institutions, Otavksy described evolving attitudes toward the contents of saintly tombs.[10] According to prevailing religious beliefs, physical contact with saintly remains endowed secondary relics with sacred properties. In contrast, a modern, secular point of view is that fine silks have independent value as historical artefacts. Even today, silks in shrines demonstrate the on-going tension between articles of religious piety and artefacts of historical interest. Silks in some religious institutions are unavailable for study; unopened shrines almost certainly contain important silks.

The earliest tomb openings occurred for one of two reasons: rites associated with translation and recognition, and reconstruction of cathedrals and abbeys that led to discovery of tombs. Several recorded tomb openings between the sixteenth and nineteenth centuries convey changing attitudes toward secondary relics. For example, in preparation for canonisation rites in Seville, the coffin of King Ferdinand III (d. 1252) was opened in 1668. Reportedly, a well-preserved garment was ripped apart by crowds eager to obtain relics.[11] Two early accounts describe the luxurious silk garments found in papal tombs that were reinterred with their contents. According to an account in 1578, the body of Pope Gregory VII

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[9] Cooke 1990, 3-11. For conditions leading to degradation of silk, see Garside and Wyeth 2002; Garside and Wyeth 2007; Peacock 1996; Becker, Magoshi, et al. 1997.
[10] Otavsky 1995, 12.
[11] Arco 1954, 232-233.

(1073-1085) was observed in fine garments woven of silk and gold.[12] In 1605 Giacomo Grimaldi meticulously recorded Pope Boniface VIII's vestments including figured silks.[13]

The tomb of Charlemagne at Aachen Cathedral was opened in 1843 and the remains removed. In 1851 Cahier and Martin published a description of the tomb contents including valuable figured silks.[14] Some other major tomb openings with finds of important figured silks are the shrine of St. Servatius at Maastricht in 1863 and the relics of St. Hippolytus at St. Ursula Church, Cologne in 1871.[15] In 1893 a casket containing anonymous relics wrapped in fine silks, originally in the abbey of St. Pierre, was opened at Sens Cathedral.[16] Several scholars have published detailed analyses of textile relics from St. Cuthbert's tomb at Durham Cathedral.[17]

The tomb of Pope Clement II (1046-1047) in Bamberg Cathedral was opened in 1949 and the textiles and metalwork were removed for conservation.[18] Apparently dating from the time of the Pope's interment, the tomb contained a silk veil woven with a mirrored kufic inscription 'Blessing for Allah'.[19] Other garments accompanying the body were a cope, chasuble, dalmatic, buskins, *cingulum*, stole, gloves, and some other fragments. The vestments were exhibited in Munich in 1955 and are now housed in the Diocesan Museum in Bamberg.

The shrine of Hildesheim Cathedral provides an example of a modern reliquary opening connected with silk. In 1997 the bishop and chapter decided to commemorate the 1500th

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[12] Paravicini Bagliani 2000, 136-139.
[13] *Grimaldi*, 38-39.
[14] Cahier and Martin 1851, 233-263.
[15] Bock and Willemsen 1872; Stein 1882, 22.
[16] Chartraire 1897; also see Muthesius 1989b, 345 n. 9.
[17] See Flanagan 1956, Granger-Taylor 1989.
[18] Müller, Steingräber, et al. 1955.
[19] Müller-Christensen 1960.

anniversary of Saint Epiphanius, a patron saint of the Cathedral.[20] His remains, along with those of several other saints and martyrs, were stored in a large reliquary. When the shrine was opened, the inner wrapping of the relic bundle was found to contain a one metre square silk patterned with birds in pearled roundels. The shape of the fragment indicates that it was cut and stitched for another purpose before being used as a wrapping.[21]

Given the historical and religious values associated with silks recovered from church tombs, most fragments were retained by religious institutions. An early exception comes from the 1781 opening of the tombs of Roger I, Henry VI, and Frederick II in Palermo.[22] Some of the rich textiles from these tombs eventually came into museums in Vienna, London, Dusseldorf, and elsewhere.[23]

Not all textiles found in tombs survived the circumstances of their recovery. Fifteenth- and sixteenth-century accounts for St. Peter's in Rome document the destruction of cloths found in tombs to recover gold. For example, the chronicle of Nicolò della Tuccia of Viterbo relayed an account of textiles in imperial burials being melted down for gold.[24] In 1458 graves were discovered in the chapel of St. Petronilla. The tombs were said to contain the bodies of 'Constantine' and his son wrapped in a golden cloth. When melted, the cloth yielded sixteen pounds of gold, which Pope Callixtus III (1455-1458) sent to the mint.[25]

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[20] Schorta 2000, 45.
[21] Schorta 2000, 47.
[22] Daniele 1784, 22-23, 43-46; 64, 102-106.
[23] Otavsky 1995, 13.
[24] *Tuccia*, 256; tr. from Lanciani 1896, 202.
[25] For the identity of the burial as Galla Placidia (d. 450) and her son, Theodosius III, see Johnson 2009, 171-172.

The diary of Marcantonio Michiel documents other finds of gold cloth.[26] In 1519 renovations unearthed several antique coffins. One contained a body wrapped in a gold pall and was accompanied by jewelry. The gold was reportedly melted down to make a new reliquary for the skull of St. Petronilla. Other treasures were discovered in a tomb found in 1544.[27] Burial goods supported identification of Maria, wife of Emperor Honorius (395-423). The body of the empress was clothed in a robe of woven gold with a veil and shroud of the same material. When melted, the material yielded a gold weight of thirty-five to forty pounds.[28]

During the nineteenth and twentieth centuries, the official character of many tomb and reliquary openings kept much of the material recovered from shrines out of private collections.[29] One exception was the tomb of Saint Bernard Calvo, Bishop of Vich (d. 1243). The saint's remains were interred in a marble tomb in 1382, transferred to a chapel in 1694, and placed in a silver sarcophagus in 1728.[30] In the 1888 recognition, the tomb contents were found to have decomposed and were refurbished by the chapter. Some of the silk fragments removed from the tomb were given away as relics; others entered the collection of the newly inaugurated Museo Episcopal. Several well-preserved fragments came into the hands of art historian Francisco Miguel y Badía and were subsequently sold to a number of collections, including the textiles now held by the Cooper Hewitt in New York.[31]

In addition to silks recovered from tombs and reliquaries, a number of historical pieces have been found in the treasuries of major churches and cathedrals. Figured silks were often

[26] Cicogna 1860, 404-405.
[27] For a list of contemporary or near contemporary accounts of this find, see Johnson 2009, 247 n. 251.
[28] For discussion of primary accounts, see Johnson 2009, 173-174, 247 n. 251.
[29] Otavsky 1995, 14.
[30] Gudiol y Cunill 1913.
[31] Otavsky 1995, 13.

used for church furnishings such as hangings, covers, and palls placed over tombs and shrines. Many of the silks now in treasury collections were formerly housed in reliquaries or tombs. Since records of removal were kept only rarely, silks can only be matched with particular tombs or shrines in a few instances.[32] Major church treasuries containing quantities of luxury textiles include: Aachen, Cologne, Bamberg, Liege, Sens, Maastricht, and the Sancta Sanctorum in the Vatican.

Chartraire expanded his 1897 inventory of the Sens Cathedral Treasury into a 1911 publication devoted exclusively to valuable textiles.[33] Schmedding's 1978 catalogue of medieval textiles in Swiss churches and monasteries documents the form and condition of the materials. Fragments survive in all sorts of shapes and sizes, ranging from uncut wrappings to small scraps cut from old vestments. Some silks were sewn into the reliquary bags preserved in a number of museums and treasuries.[34]

Stauffer's 1991 catalogue of the medieval textiles found in the treasury of St. Servatius in Maastricht documents the diversity and condition of surviving fragments. In addition to silks attributed to Byzantium between the seventh to eleventh centuries, the collection includes patterned materials identified as: fourth- to seventh-century Eastern Mediterranean, Byzantine and Islamic Egypt, early medieval China, tenth- and eleventh-century Central Asia and Turkestan, ninth- to fourteen-century Spain, and thirteen- and fourteen-century Italy.[35]

A number of silks have been preserved in illuminated manuscripts as part of exterior bindings, interior linings, and inserted cloth sheets to protect illuminations. While various authors have studied fine ecclesiastical bindings, no comprehensive cross-collection survey of

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[32] Muthesius 1982, 264.
[33] Chartraire 1911.
[34] For example, see Schmedding 1978, 25, f. 11; 31, f. 14; and Muthesius 1995f, Pl. 19.
[35] Stauffer 1991.

medieval silk book bindings exists, and many of the silks incorporated into manuscripts remain unpublished.

Wilckens analysed the silk bindings on several volumes held in German collections including the Fuldaer Gospels at the Würzburger University Library.[36] Her analyses show that some of these silks have characteristics indicating re-use of materials from church vestments including seams and traces of embroidery. In some bindings, the warps are oriented in different directions, suggesting efforts to incorporate scarce materials. Muthesius published a detailed description of the silk binding construction method used for the Mondsee Gospel Lectionary in the Walters Art Museum in Baltimore.[37]

Two of the most beautiful and well-preserved silks are in the ninth-century Lindau Gospels at the Pierpont Morgan Library in New York.[38] Written and illuminated at the monastery of St. Gall, Switerland, the silks in the upper and lower interior covers are attributed to early ninth-century workshops in Byzantium and Baghdad respectively. The manuscript was the property of the Abbey and Chapter of the Noble Canoness of Lindau on Lake Constance until it was dissolved in 1803. After moving through various hands, the manuscript was eventually acquired by J. Pierpont Morgan in about 1883.[39]

The Theodulf Bible (ca. 810) is one of the most remarkable survivals of ancient textiles bound into manuscripts, and has been examined by several researchers.[40] The bible was made for bishop Theodulf of Orléans (ca. 750-821), a theologian and advisor to Charlemagne. At least fifty-three cloth sheets were inserted to protect the luxury illuminations and calligraphy

[36] Wilckens 1990.
[37] Muthesius 1995d.
[38] Elsberg 1933.
[39] Elsberg 1933, 11.
[40] For example, see Michel 1852, 68-70; Sabbe 1935a, 816; Pfister 1950; Viseux 1993.

of which forty-seven now survive. The sheets comprise a wide range of materials including silk, cotton, linen, and goat and camel hair in a variety of weave structures including samite.[41] Some of the patterned pieces are attributed to Arab and Coptic workshops, but dating and more specific assignment on technical grounds is problematic.[42]

b. Silk from Egyptian cemeteries

The second major source of figured silk remains is late antique and early Islamic cemeteries adjacent to urban settlements in the Upper Nile Valley. Desert conditions inhibited decomposition and preserved many grave goods in a desiccated state. Napoleon's expeditions to Egypt (1798-1801) stimulated interest in antiquities including textiles.[43] Early finds, reportedly from Saqqârah, are now in various collections including Turin, the Louvre, and the British Museum.[44] Long overshadowed by Pharaonic treasures, material from later historical periods was often overlooked or destroyed by excavators.[45] During much of the nineteenth century, uncontrolled digging produced various artefacts, spurring active trade in Egyptian antiquities.[46] As cloths found in Egyptian sites came onto the market, appreciation grew for their design and technique, which were considered to be relevant to contemporary European textile manufacturing.[47]

In 1883 Gaston Maspero, Director of the Egyptian Antiquities service, identified Akhmim graves as a source of 'fine mummy cloths'.[48] In subsequent years, thousands of

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[41] Viseux 1993.
[42] Viseux 1993.
[43] Kendrick 1920, 4.
[44] Kendrick 1920, 4.
[45] Stauffer 1992, 13.
[46] For an overview of archaeological textiles finds from various excavations in Egypt, see Vogelsang-Eastwood 1988, 77-150.
[47] Forrer 1891, *Einleitung*.
[48] Capart 1936, 244.

bodies in late Roman and early Islamic cemeteries were unearthed through excavations and clandestine digging. Accounts by excavators, travellers, and collectors describe the massive scale and chaotic handling of material.[49] In one report, bodies removed from graves were piled in huts awaiting buyers to select materials.[50] In 1894 Robert Forrer, an antiquities collector and dealer, directed excavations at Akhmim. His letters describe a landscape marred by opened graves and littered with picked-over corpses.[51] Some excavators and dealers treated find locations as a secret to preserve the source of their supply.[52]

Theodor Graf, a carpet dealer based in Vienna, was among the first antiquarians to search for material in Egypt. Following discovery of papyri in the Fayum in 1881, Josef von Karabacek, a professor of Oriental Studies in Vienna, urged Graf to look for papyri.[53] Graf subsequently acquired the material now in the collection of the Österreichische Nationalbibliothek. Karabacek also encouraged Graf to search for cemeteries to find textiles.[54] Graf's agents ultimately found a large late Roman and Christian necropolis in the Fayum in 1882. Material was clandestinely excavated and shipped to Europe where it was later sold to museums in Vienna, Berlin, Lyon, St. Petersburg, and New York.[55]

Rich artefact finds spurred excavations at Ahkmim and other sites. As a respected scientist, Georg Schweinfurth conducted extensive topographical surveys of Arsinoë in 1884 and 1886 to obtain specific site information from a 'great heap of ruins'.[56] In the course of this work, Schweinfurth also collected about 450 textiles from the site which were mainly

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[49] For a summary of accounts, see O'Connell 2008, 2-4.
[50] Budge 1920, 1: 87.
[51] Forrer 1895, 29-37.
[52] Karabacek 1883, 4.
[53] Fluck, Linscheid, et al. 2000, 125.
[54] Fluck 2005, 144.
[55] Fluck 2005, 144. For a description of methods, see Karabacek 1883, 24-25.
[56] Schweinfurth 1887, 54.

donated to the Ägyptisches Museum in Berlin.[57] Contemporaries included M. Wladimir Bock, who excavated at Aswan, Akhmim, and other sites in the Fayum for the Hermitage Museum.[58] During the 1885-1886 season, Canon Dr. Franz Bock also excavated in Upper Egypt.[59]

Albert Gayet began his excavations of the cemeteries of Antinoë in 1896 and continued until 1911.[60] Artefacts recovered from the site and displayed at the Musée Guimet in Paris included a wide variety of grave goods such as textiles, shoes, masks, and mummy paintings.[61] With backing from sponsors including the French government, the Lyon Chamber of Commerce, and the Guimet, Gayet boasted that he opened 2,000 graves during the two-month excavation season in 1898.[62] Gayet was a flamboyant figure and organised numerous exhibitions and displays of Coptic materials including the 1900 Exposition Universelle de Paris.[63]

Reports and early photographs show that many bodies removed from major find sites were dressed in multiple layers of clothing, and then wrapped in a shroud bound by cloth tapes. Forrer recorded his observations as he unwrapped some mummy bundles and noted differences between apparently richer and poorer burials.[64] Buyers selected ornamented and embellished pieces while plain or damaged items were discarded. Artefacts found together were separated and the finest pieces were sometimes cut apart to increase sales revenues. A recent study of textiles from Egyptian burying grounds demonstrated that surviving fragments

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[57] Fluck 2005, 144.
[58] Fluck 2008, 213.
[59] Fluck 2008, 213. Note that Fluck suggested that the source of Bock’s large collection is a cemetery near Akhmim.
[60] Bénazeth 2006, 69.
[61] Gayet 1898.
[62] Gayet 1898.
[63] Gayet 1900.
[64] Forrer 1895, 43-48.

mainly come from the outer extremities of garments, such as ends of sleeves, neck sections, and sides. Cloths near the centre of the bodies were usually damaged by fluids.[65] Remnants often show traces of embalming substances, skin and blood, and include grit and plant remains.[66]

Accounts of the excavations indicate that an enormous quantity of textile goods and artefacts were taken from burying grounds in Egypt during the late nineteenth and early twentieth centuries. Fragments are widely dispersed in public and private collections in North America, Europe, and Asia. Estimates of the consolidated mass of material vary widely. In 1971 Thompson estimated the number of textile artefacts to be around 150,000 pieces.[67] Gervers suggested the quantity to be closer to 100,000 items.[68] A more accurate picture of the amount of material would require extensive cross-collection collaboration and more specific definition of characteristics including date and culture.

Among these finds, silk was a highly visible subset of the material. According to Schweinfurth, woven silk garments and tapestries were found only rarely.[69] In many instances, silk was combined with linen to form a striped pattern. Forrer also reported that silk garments finds were rare.[70] Instead, he observed that whole silk squares, rectangles, ovals, and round decorative pieces were commonly sewn on to tunics.

When textiles were eventually accessioned into museum collections, available provenance information was carried over into collection records. The problem is that even when material came directly from an official excavator, the reported find spot should be

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[65] Fluck 2005, 146.
[66] For a description of the condition of excavated textiles, see Blair, Bloom, et al. 1992.
[67] Thompson 1971, 4.
[68] Gervers 1977, 66.
[69] Schweinfurth 1887, 71.
[70] Forrer 1891, 10-11.

treated with caution. Recordkeeping practices were poor and materials bought at a site may have been found elsewhere.[71] As Fluck has shown, even Schweinfurth's carefully numbered and labelled finds came into travellers' hands and were held in collections elsewhere.[72] Consequently, the normal convention among curators is that provenance is not proven or reliable for any sites, even for early acquisitions.[73] According to O'Connell, acquisition date can provide qualified evidence, but only in combination with artefacts that have similar characteristics.[74]

5.2 Technical Museums

As a reflection of the broad industrial and societal changes that occurred during the mid-1800s, textiles took on a new role as a shared resource to support commercial interests and to elevate general levels of public taste.[75] Valuable textiles, including those recovered from religious shrines and archaeological contexts, were gathered into the newly formed collections of industrial museums. Historically, textile producers maintained cloth samples as a proprietary resource for technical reference. Gathered into public collections, ancient textiles became models for contemporary applied art.[76] In testimony to the changing role of figured textile artefacts over time, the same materials that embellished Egyptian burials or were imported for elite use in Europe and later revered as secondary relics, became ornamental models for students of commercial design.

The first museums devoted to textile art were located in manufacturing centres as a response to concerns about industrialisation and the quality of applied arts, and coincided with

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[71] Vogelsang-Eastwood 1988, 104.
[72] Fluck 2005, 144.
[73] Fluck, Linscheid, et al. 2000, 131; O'Connell 2008, 4.
[74] O'Connell 2008, 4-5.
[75] For a discussion of the intended role of technical museums, see Martiniani-Reber 1986, 7.
[76] Geijer 1979, 271.

the Arts and Crafts movement.[77] In 1864, the Lyon Chamber of Commerce founded the Musée d'Art et d'Industrie to form a collection directly related to textiles. The aim was to create a civic institution to promote textile arts and provide a set of references specific to quality design.[78] A weaving school was founded in 1884 as another means to elevate fine arts and technique. Similar institutions were established in other commercial and industrial centres including Krefeld, Berlin, Paris, London, Manchester, and Florence.[79]

As in Europe, museum founders in North America wanted to elevate the quality of manufactured goods and provide access to historical examples of good design.[80] In 1870, Boston was the centre of the United States' textile industry. A permanent collection was formed through purchases and donations, and a variety of exhibitions were arranged to present these materials to the public.[81] Between 1893 and 1920, the museum built its Coptic textile collection through a series of private gifts.[82] At the same time, similar collections were formed in other major industrial cities including New York, Cleveland, Detroit, and Toronto.

Many museums with textile collections made their holdings available for study purposes. For example, in 1898 the Boston museum opened a textile study room accessible to students and designers.[83] Similar resources were established in many European and North American institutions. At the Metropolitan Museum of Art in New York, visitors could record their observations of textile samples by making their own ink or watercolour drawings.[84] Rectangular fragments containing one or more pattern repeats were affixed to boards for

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77 Martiniani-Reber 1986, 7.
78 Martiniani-Reber 1986, 7.
79 Martiniani-Reber 1986, 7.
80 Salmon, Kvaraceus, et al. 1980, 3.
81 Salmon, Kvaraceus, et al. 1980, 3-4.
82 Gifts of Denman Ross, see Salmon, Kvaraceus, et al. 1980, 4.
83 For example, see Salmon, Kvaraceus, et al. 1980, 4; DIA 1930, 83.
84 MMA 1915, 3-4.

study purposes.[85] Textile clubs affiliated with some museums provided a forum for public education and facilitated participation and fund-raising.[86]

The form of the material preferred by collectors was a single visual repeat. Private collections were often organised by ornamental characteristics and arranged on paper or wood boards like plates in a book.[87] Interest in ornamental designs arranged according to contemporary tastes was characterised by Gayet's own personal albums published by Hoskins.[88] In this pair of volumes, textiles and grave goods were displayed in fanciful pastiche arrangements. Over time, the fragile nature of these materials and their vulnerability to damage from exposure and handling became evident, and materials were eventually withdrawn from wide public access.

5.3 Dealers and Collectors

Some of the first silks to pass into public and private collections came from anonymous or abandoned churches or were sold by destitute church treasuries. With increasing secularisation, religious institutions were abolished and their property sold.[89] The discovery of artefacts in Egypt was a boon to the antiquities trade from the 1880s through the 1930s. Demand created by collectors stimulated excavation activity, both official and illicit, and spurred an industry of fakes that has yet to be fully recognised in institutional collections.[90] Because modern collections were built largely with material acquired from dealers and private

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85 A 1915 photograph of patrons in Boston's textile study room is included in Salmon, Kvaraceus, et al. 1980, 7. A photograph of work tables and storage shelves appears in MMA 1915, 3.
86 Wardwell 1984, 1.
87 For a description of collector textile albums, see Thomas 2007, 140-142.
88 Hoskins 2004.
89 Otavsky 1995, 17.
90 The most widely published group of recognised fakes were the so-called Buyid textiles sold by Pope and Ackerman. Recent publications include Blair, Bloom, et al. 1992; Méthé and Krody 2007.

owners in the early twentieth century, the antiquities trade, and the aesthetic ideals that it represented, have had a lasting effect on the form and nature of existing museum textile collections.

Exploration of the large network of dealers and collectors active in the last half-century of colonial rule in the Middle East represents a fascinating convergence of circumstances leading to the large scale transfer of material into the market. The social identity of collectors varied widely. Many buyers were foreign tourists or had business interests in the region. For example, Erikson described the important collection developed by Tove Alm who worked in Cairo as a nursemaid.[91] During the same interval, Queen Victoria of Sweden travelled to Egypt in 1892-1893, and purchased Coptic and early Islamic textiles that were then donated to museums. The crown prince, later King Gustaf VI Adolf of Sweden, purchased textiles and funded acquisitions by Carl Johan Lamm, who subsequently published his technical analyses in *Cotton in Mediaeval Textiles of the Near East*.[92]

A comprehensive description of the network of dealers and major collectors and their interactions is beyond the scope of this work. Some well-documented collection catalogues for museums in Lyon, Paris, and Berlin identify the dealers and collectors most important to their respective collections.[93] Since the majority of ancient textiles entered collections with little or no provenance information, two factors provide at least a measure of credible collections information: accession date and association with a major collector or dealer. In general, fragments with early accession dates are regarded as more secure on the grounds that

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[91] Erikson 1997, 23-31.
[92] Lamm 1937.
[93] See for example, Martiniani-Reber 1986, 8-9; Desrosiers 2004, 8-10; Wilckens 1992, 9-10. Some highly regarded dealers in these catalogues included: Baron, Bock, Côte, Forrer, Loewi, Mallon, Pozzi, Schmitz and Tano.

a credible fake industry would have taken time to develop. Second, in the absence of specific information, dealer reputation is considered important.

During the second half of the nineteenth century, distinctive ownership roles evolved among persons handling ancient textiles including finder, excavator, dealer, collector, and donor. In practice however, many individuals participated in several activities. Excavators became dealers and collectors, dealers maintained their own private collections, and collectors divided and exchanged textile samples among themselves. The following is a brief description of three major collectors active between the late 1800s and the first half of the twentieth century, each of whom had a major impact on present collections and scholarship.

Canon Dr. Franz Bock (1823-1899) gathered some of the most important textiles now held in the collections of leading museums. Bock combined his religious offices as an ordained priest with study of ecclesiastical art, particularly textiles. Between 1859 and 1871, he published a three-volume work devoted to documenting and reviving the art of medieval religious vestments.[94] Bock was an aggressive collector and used his privileged access to treasuries and shrines in Belgium, Holland, Switzerland, and Germany, not only to study the materials, but also to cut samples that he later sold.[95] Through his collecting trips around Europe and to the Near East, he amassed substantial collections of textiles and other objects.[96]

Bock's collecting activities coincided with the formation of applied arts museums eager to build their collections with quality materials. Records show that between 1858 and 1875, he sold large quantities of materials to the Kensington Museum London (now the V&A), the Musée d'Art et d'Industrie, Lyon, and the Österreichische Museum für Kunst und Industrie,

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[94] Bock 1859-1871.
[95] Borkopp-Restle 2008, 86-94.
[96] Pritchard 2001, 48.

Vienna.[97] He also served as an advisor and arranged exhibits to display textile arts.[98] In 1883 the city of Manchester purchased the remainder of his collection to provide the core of a textile collection available to students of textile design.[99]

Isabella Errera (1869-1929) was the wife of an art collector and professor in Brussels. Together with her husband, she hosted a popular weekly salon for intellectual and artistic elites and was influential in transmitting the ideas of William Morris and the Arts and Crafts movement.[100] Errera was avid in her textile interests and developed her collection over four decades beginning in 1891. In building her collection, Errera's aim was to trace the evolution of taste in decoration through the ages by documenting textile ornamentation.[101]

Errera was probably introduced to a circle of textile experts through her uncle, Baron Giulio Francetti (1840-1909), who donated his extensive collection acquired from churches and antiquarians to what is now the Bargello Museum.[102] Many of Errera's specimens were purchased from international dealers in Paris, Spain, and Italy.[103] She acquired a large group of Egyptian textiles from Bock, as well as some items from Forrer. She also bought some textiles from the Königlichen Kunstgewebemuseums in Berlin and exchanged some duplicate pieces.[104] Beginning in 1901, Errera produced a series of well-illustrated catalogues that are notable for their modern form and appearance.[105] Errera's large collection was bequeathed to the Royal Museums of Art and History in Brussels where it forms the core of the present collection.

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[97] Pritchard 2001, 49.
[98] Borkopp-Restle 2008, 146-152.
[99] Pritchard 2001, 50.
[100] Raemdonck 2006, 78 n. 7.
[101] Raemdonck 2004, 5.
[102] Fanelli and Peri 1981, 14.
[103] Raemdonck 2006, 75.
[104] Raemdonck 2004, 7 n. 16-18.
[105] Errera 1901; Errera 1907; Errera 1916; Errera 1927.

Werner Abegg (1903-1984) was a textile manufacturer and art collector. His main interests were medieval and Renaissance applied art. He began building his textile collection as a young man in Turin during the 1920s and rapidly became an important buyer.[106] The core of his collection was formed from auctions of older groupings that were owned by Albert Figdor as well as from dealers including Adolfo Loewi in Venice and Dikran Garabed Kelekian in New York.[107] A Kelekian textile exhibited at the Byzantine Exposition in 1931 was the first late antique textile purchased by Werner Abegg.[108] During the 1930s, Abegg began buying directly from religious institutions forced to sell their art.[109] To escape World War II in Europe, both Abegg and Lowei relocated to the United States. Abegg moved to New York where he continued to build his collection; Loewi resumed his decorative and fine arts business in Los Angeles and became a major source of medieval textiles for American museums.

In 1961 Abegg and his wife, Margaret, established the Abegg Foundation in Riggisberg, Switzerland. The foundation now includes a museum devoted to presenting textiles as well as other fine and applied arts in permanent and special exhibits. Today, the Abegg Foundation is the most active publisher of historical textile research associated with the core focus of the Riggisberger textile collection: late antique tapestries, medieval materials, and fine fabrics of the sixteenth to eighteenth centuries.

Apart from the Abegg Foundation and a handful of other private museums such as Katoen Natie in Antwerp, most private collections built up by wealthy collectors have passed into public institutions, either through donations by heirs or resale in the arts market. In 2002,

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106 Fillitz 2003, 55-56.
107 Otavsky 1995, 18.
108 MMA 2012.
109 Otavsky 1995, 18.

Kelekian's granddaughter donated a portfolio and album of textile samples to the Metropolitan Museum of Art. In 2008 the Keir Collection assembled by Edmund de Unger was bequeathed to museums in Berlin.[110]

5.4 Scholarly Literature

In tracing the development of historical textile research, some of the earliest studies were supported by industry associations. The Lyon Chamber of Commerce sponsored Ernst Pariset's scholarly history of silk published in 1862.[111] Finds of textiles and other artefacts stimulated public interest in post-Pharaonic history and attracted scholars to the field. In the scholarship that developed during the next fifty years, attribution judgements were based mainly on ornamental and iconographic motifs and stylistic traits.

Working with fragments in the Louvre, Fischbach's 1874 study of textile ornament predates the recovery of most archaeological material from Egypt.[112] In 1891 Forrer published two books asserting a difference between local Egyptian textiles and the relatively rare silk finds that he considered to be imported goods.[113] Forrer's segregation of material on the basis of style and construction demarcated the boundaries of an attribution discussion that continues to the present.[114] Forrer reasoned that because Byzantium imported silk through Persia, and that Alexandria was known to have had an imperial textile factory, silks found in the Fayum could be attributed to an Alexandrian workshop.[115] In 1903, Strzygowski presented an alternate perspective. He considered the silks found in Antinoë to be artistically and

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[110] SMB 2009.
[111] Pariset 1862.
[112] Fischbach 1874.
[113] Forrer 1891 and Forrer 1891. See Fluck 2008, 214 for the observation that when Forrer wrote his books, he had not excavated himself and relied upon reports from dealers in Cairo.
[114] For recent evidence pertinent to stylistic analysis, see De Moor, Schrenk, et al. 2006.
[115] Forrer 1891.

technically superior to other material found at the site and attributed the finds to Sassanid Persia.[116]

Beginning in the late 1800s, catalogues became one of the main vehicles to support exhibitions and make collections accessible to scholars and the general public.[117] In 1883 Karabacek organised an exhibit in Vienna accompanied by a catalogue.[118] Expanding on Karabacek's work, Riegl produced an exhibition catalogue notable for its technical description of materials and techniques. Based on his examination of the material, Riegl associated the motifs with an international decorative style influenced by Roman, Persian, and Byzantine characteristics.[119]

Publications to document and present ancient textile collections to a broader audience include Blanchet's 1897 folio with heliograph reproductions of important textiles attributed to Byzantium and other production centres.[120] In Berlin, Julius Lessing, director of the Königlichen Kunstgewebemuseums, produced a series of large portfolios illustrating fine silks in the collection between 1900 and 1909.[121] His successor, Otto von Falke, reconceived the project into a developed geographical and chronological classification scheme. In 1913 Falke published an extensively illustrated history of decorative silks.[122] While elements of his classification scheme have been revised by subsequent scholarship, Falke's two-volume work remains an essential resource for textiles historians.

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[116] Strzygowski 1903, 147-178.
[117] For a discussion of the role of catalogues in textile documentation, see Thomas 2007, 139.
[118] Karabacek 1883.
[119] Riegl 1889, XXIV. See also Thomas 2007, 142-144.
[120] Blanchet 1897.
[121] Lessing 1900-1909.
[122] Falke 1913.

During the next twenty years, museum-based scholarship continued to develop based on professional recognition of curatorial work and interest in moving beyond surface decoration to consider structural characteristics. In 1914 Cox published a catalogue describing the fine silks in the Musée historique collection in Lyon.[123] At the Victoria and Albert Museum in London, both A.F. Kendrick (Keeper of Textiles 1897-1924) and A.J.B. Wace (Deputy Keeper of Textiles 1924-1934) made important contributions to materials-based scholarship through their interest in the technical attributes of complex weaves.[124] A pair of catalogues devoted to the burying grounds of Egypt and 'early medieval' woven textiles provide astute observations relevant to material analyses today.[125]

In 1926 Wulff and Volbach published a catalogue of late antique and Coptic textiles in German state museums.[126] Recognising that archaeological evidence was available only in exceptional cases, the authors sought to demonstrate the parallel development of motifs with technological developments.[127] Given the nature of the evidence, the authors proposed a scheme defined in terms of relative classes within a broad timeframe. For figured silks, the authors carried forward the alleged find spot based classification scheme published by earlier scholars with silks attributed to Antinoë, Akhmim, or Alexandria.[128]

Other textile discoveries in the early 1900s contributed new evidence to a chronology of developments in weaving technology. Sir Aurel Stein's three excavations to Central Asia between 1900-1916 yielded a diverse quantity of textiles from various Silk Road contexts

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[123] Cox 1914.
[124] Wilson 1995, 45.
[125] Kendrick 1920, Kendrick 1925.
[126] Wulff and Volbach 1926.
[127] Wulff and Volbach 1926, IX.
[128] Wulff and Volbach 1926, 145.

including forts, shrines, and burying grounds.[129] Collectively, the materials recovered from Stein and subsequent excavations provide a body of evidence to frame the exchange of artistic and technical influences between regions to the east and west.

Textual and material-based studies have shown the westward movement of woven silks from East Asia beginning with the warp-faced compound tabbies of the Han dynasty (206 BC to AD 220).[130] Technical and art historical analyses of archaeological textiles found at various sites demonstrate that by the early medieval period, trade in woven textiles was reciprocal and flowed in both directions along trade routes.[131] Finds at central Asian sites include Mediterranean-style figured wool textiles and tapestry weaves with clear Greek and Persian influence.[132] The weft-faced compound weave figured silks found at Astāna are particularly important in demonstrating the eastward movement of memorised pattern technology appropriate for weaving large scale figured patterns.[133]

After World War I, the history of textile art was expanded by numerous important finds. Discovery of imported silks in Syria at Dura Europos (before 256), Palmyra (before 273) and Halabiyeh-Zenobia (before 610) provided new perspectives on dating silks as well as insights on techniques and designs. With more than 2,000 textile fragments dated by inscriptions from the first century BC to the second century AD, the finds at Palmyra are among the largest groups of textiles of proven origin.[134] In particular, the tower tombs yielded rich finds of imported Chinese silks utilised as funerary wrappings.[135] The evidence indicates that

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[129] Wilson 1995.
[130] King 1968.
[131] Vainker 2004, 44-109.
[132] Vainker 2004, 69.
[133] Yokohari 1991.
[134] Schmidt-Colinet 1995, 47.
[135] Schmidt-Colinet, Stauffer, et al. 2000; Schmidt-Colinet 1995.

quantities of embroidered silks, monochrome patterned weaves, and warp-faced compound figured silks from China were available to wealthy residents.[136]

The textile finds from Palmyra were analysed in a series of reports by Rodolphe Pfister. Pfister introduced scientific methods to historical textile analysis including fibre identification and chemical analysis.[137] Although criticised at the time, some of Pfister's ideas have yet to be fully explored because of technology limitations.[138] Pfister's 1934-1940 excavation reports established new standards for technical description of artefacts. His most important contribution was edited and co-authored by Louisa Bellinger.[139]

For the purposes of this study, a significant silk find comes from Dura-Europos and is now preserved in the Yale University Art Gallery (no. 1933-486 a,b). Originally attributed to China by Pfister in 1937, it was re-analysed and published in the 1945 report as a weft-faced compound tabby silk with Z spun warps. Some textile scholars have described this silk as a possible intermediary step in the development of silk weaving technology in the Eastern Mediterranean region.[140] Since textiles found at the site have a *terminus ante quem* of 256, this find suggests that a silk weaving industry existed in the region by the third century.

During the same era, J.F. Flanagan (1884-1956) made important contributions to the analytical study of early textiles. Born in Macclesfield, the centre of the English silk-weaving industry, Flanagan trained as a weaver and designer, eventually becoming a teacher at Saint Martin's School of Art and head of the Royal College of Art weaving department.[141] Flanagan

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[136] Schmidt-Colinet 1995.
[137] Pfister 1934; Pfister 1937; Pfister 1940; Pfister and Bellinger 1945.
[138] For example, see Flanagan 1935; Flanagan 1944.
[139] Pfister and Bellinger 1945.
[140] See Becker 1987, 95-96; Riboud 1974.
[141] Granger-Taylor 1992, 187.

owned a textile mill specialising in high quality furnishing and church textiles.[142] Throughout his career, Flanagan conducted his own studies of technical weaving developments and published a series of articles between 1919 and 1946.[143] His analysis of early Byzantine silks provides one of the first technical analyses demonstrating the independent development of drawloom weaving in the West and its relationship to tapestry weaving.[144] Through his publications, Flanagan demonstrated the value of technical textile analysis as a source of information complementary to conventional textual and art historical methods.

5.5 Technical Analysis

As part of a broader trend to make better use of collections and to put more focus on textiles, several museums appointed textile curators in the 1920s and 1930s. In 1952, Adele Coulin Weibel, former textile curator at the Detroit Institute of Arts, published the only survey to date of figured textiles in North American collections.[145] This work, as well as other compilations, demonstrate that the cosmopolitan nature of Eastern Mediterranean and Islamic weaving centres resulted in extensive cross-cultural exchange and sharing of common themes.[146]

As a curator at the Textile Museum in Washington, DC from 1946-1964, Bellinger made a lasting contribution to technical textile scholarship through the *Workshop Notes* report series that included microscopic photographs and technical illustrations rarely published elsewhere.[147] At the Cleveland Museum of Art, Dorothy Shepherd served as Curator of Textiles and Near Eastern Art from 1954-1981. Her extensive scholarship of medieval silk

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142 Granger-Taylor 1992, 187.
143 See Flanagan 1919; Flanagan 1934; Flanagan 1936; Flanagan 1944; Flanagan 1946.
144 Flanagan 1919.
145 Weibel 1952.
146 Sonday 1987, 57.
147 Bellinger 1950-1961.

textiles includes a number of piece specific studies.[148] Donald King authored some of the most important technical contributions in the field during his more than thirty years in the Textile Department at the Victoria and Albert Museum.[149]

An on-going problem in historical textile studies has been development of common characterisation methods for specific analysis and comparison.[150] Lacking an accepted standard lexicon, most curators applied their own technical descriptions to collections under their care. In 1937, Reath and Sachs published a comprehensive classification system for Persian textiles dated from the sixth to eighteen centuries.[151] This work represented one of the first systematic approaches to technical weaving documentation of historical textiles in a form accessible to non-specialists. Over time, significant inconsistencies developed within individual collections and among different institutions. To illustrate this point, Vogelsang-Eastwood compiled a list of twenty-one terms used by different researchers to describe weft-faced compound weave structures (appendix 5.1).[152]

The enormous variety of materials and processes used to create textile objects makes development of a comprehensive classification system problematic. Various recording and classification schemes have been developed over time, which differ based upon the time period, materials applied, and material origins. The classification systems most widely applied to ancient silks are: CIETA, 1964; Emery, 1966, 1980; and Seiler-Baldinger, 1979. Documentation and research problems have led other scholars to propose schemes appropriate

[148] For example, see Shepherd 1960; Shepherd and Vial 1965; Shepherd 1952.
[149] For example, see King 1966; King 1981; King 1987.
[150] Cooke and Peacock 1992, 223.
[151] Reath and Sachs 1937.
[152] Vogelsang-Eastwood 1988.

to particular research approaches, including those presented by Walton and Eastwood, Nelson, and El-Homosanni.[153]

In 1954 CIETA was founded in response to concerns about the state of post-war European textile collections.[154] Initially proposed by W.F. Volbach, the organisation was established at the Museé des Tissus in Lyon to coordinate conservation and research efforts for historical textiles.[155] The analysis framework now known as the 'CIETA method of technical analysis' was based on various weaving manuals, notably a volume published by Felix Guicherd, a weaving instructor at L'école de tissage in Lyon.[156] In 1957, CIETA published a template for textile analysis known as the 'dossier' (*dossier de recensement*) that remains in use to the present (appendix 5.2).[157] A series of analyses published in the *CIETA Bulletin* by Guicherd, Micheaux, Vial, and others provided a template for my detailed piece-specific research.

5.6 Attribution

The collective result of nearly a century of scholarship associated with historic silks attributed to Near East and Mediterranean workshops has been definition of a broad scheme showing the technical progression of weaving technologies in the region. Geijer was one of the first to present a synthesis of textile technology developments to a broader audience.[158] Becker's 1987 book, *Pattern and Loom*, represents a singular contribution to the field by combining research in a progression of weaving technologies with practical experiments.[159]

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[153] Walton and Eastwood 1984; Nelson 1986; El-Homossani 1988.
[154] Taylor 2006, 99.
[155] Taylor 2006, 99.
[156] Guicherd 1946. For Guicherd's contribution to the field, see Martiniani-Reber 1986, 6.
[157] CIETA 2006, 2.
[158] Geijer 1979.
[159] Becker 1987.

Published in 1991, Wilcken's *Geschichte der textilen Künste von der Spätantike bis um 1500* provides an illustrated historical survey of textile developments.[160]

While these publications describe technical developments in general terms, much work remains to be done to synthesise observations from the mainly piece-specific technical analyses found in the specialist literature.[161] Collectively, these analyses comprise an important body of research, but the field lacks a set of consolidated resources that generalise specific findings and communicate information in a form accessible to the larger scholarly community. Consequently, research pertaining to complex figured silks is poorly integrated with the larger body of material culture scholarship. Moreover, lack of synthesised research presents an obstacle to the entry of new scholars and limits research to a small number of practitioners.

A second problem is that a large proportion of detailed analyses describe the finest and most intact pieces within a collection. By focusing on hallmark pieces, conclusions may not be representative of the larger body of evidence. As demonstrated by Verhecken-Lammens in her analysis of twenty-one wool taquetés from three different collections, comparison of various technical characteristics among a large number of different pieces provides a more specific basis for defining patterns of practice.[162] Overall, the literature concerning historic complex weaves contains few examples of detailed analyses performed on a cross-institutional basis.[163] While ostensibly related pieces are usually cited in technical analyses, detailed investigations are almost always confined to a single collection. The textile history

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160 Wilckens 1991.
161 The *CIETA Bulletin* has not been published since 2004 due to a legal dispute.
162 Verhecken-Lammens 2007.
163 Examples of cross-institutional analyses include the 'Buyid' group of silks as described in the CIETA Bulletin, Issue Nos. 37, 38, 39-40 and 43-44; De Moor, Schrenk, et al. 2006.

field, and material culture studies of various cultures, would benefit from a cooperative research agenda shared by several institutions.

One hopes that a comprehensive handbook for technical analysis with clear and specific illustrations will be produced in the future. Meanwhile, the most complete resource to date was published in 2004 by Desrosiers.[164] The author defined technical analysis attributes in terms of six characteristics.[165] These include: the ratio of main to binding warps, the sequence order of inserted wefts, use of more than two colours throughout the textile, the direction of the twill diagonal binding, incidence of a coordination mistake between a weaver and assistant, and the orientation of the figured pattern to the warp.

Based on these technical characteristics, Desrosiers described the attribution framework for European and Middle Eastern weft-faced compound silks as comprising two broad periods. Period I extended from Late Rome until the eighth to ninth centuries. Textiles attributed to this first period are grouped into seven categories: wool taquetés, Christian-theme silks, 'Antinoe' silks, small pattern motif silks, 'Akhmim' silks (three subcategories), 'Alexandria' silks (red and blue sub-categories), and Eastern samites (two sub-categories).[166] A table showing the technical characteristics and sub-categories for each group is included as appendix 5.3.

According to Desrosiers, silks woven in period II, which begins in the ninth to tenth centuries and extends through the late Byzantine period, became more or less structurally homogenous with most fragments sharing the following characteristics: samite twill in an S direction with a 1:2 ratio of binding to main warps, and returning insertion of weft passes.

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[164] Desrosiers 2004.
[165] Desrosiers 2004, 14-18.
[166] Desrosiers 2004, 18-20.

Because of technical similarities, attribution is largely determined by art historical analyses. Desrosiers concluded that more work is required to define additional variables to distinguish among the silks associated with both periods.[167]

5.7 Recent Developments

In recent decades, scientific excavations at a wide variety of sites in Egypt have yielded textile evidence that provide a more balanced understanding of silk in context. Excavations of the fourth-century Christian cemetery at Khargeh in the remote Western Egyptian desert have produced a number of linen and wool textiles, but no silk.[168] Finds from excavations during the early 1900s at the site included only two artefacts containing silk: a belt and a tapestry fragment.[169]

Although the ninth- to tenth-century monastic cemetery at el-Ghalida was heavily disturbed by illegal excavations in the 1990s, scattered debris included several linen and wool fragments with silk decorations or trim.[170] Several embroidered and tapestry woven silks were found in the eleventh- to thirteen-century Christian cemetery adjacent to the Monastery of Nekloni (al-Naqlūn) in the Fayyūm.[171]A small number of silks have been found in excavations in Israel beginning in the Byzantine period, and become more common after the ninth century.[172] Silk remains were found in Nessana, ‘Avdat, and Nahal ‘Omer.[173]

Excavations at Amorion in Turkey have yielded rare finds of silk, securely dated to the middle Byzantine period. Coins of Nikephoros II (936-969) provide *terminus post quem*

[167] Desrosiers 2004, 21.
[168] Letellier-Willemin 2011, 107-109.
[169] Letellier-Willemin 2011, 107-109.
[170] Huber 2011.
[171] Godlewski 2006.
[172] Shamir 2001, 103.
[173] Shamir 2001, 103.

dating for the construction of the tombs where silk textiles were found in the narthex of the lower city church.[174] Although many of the textiles are extensively degraded, certain technical details are evident. At least one outer garment was constructed from a weft-faced compound weave silk.[175] The neck of another garment was trimmed with a textile containing medallions, although the material and weave are undetermined.[176] A tabby weave shroud was embellished with silk-embroidered appliques in the shape of roundels.[177] One fragment contains gold foil 'Z' wrapped yarn that was applied to a tabby silk with couching stitches.[178] These finds are significant because they provide specific archaeological evidence of silk and gold in luxury textile use outside of Constantinople in the tenth century.

Consistent with the patterns observed by Schweinfurth and Forrer, recent excavations demonstrate that finds of intact whole silk articles are rare. Material recovered from non-imperial contexts shows that silk textiles were more commonly used on a divisible basis. Fragments of patterned silk textiles were sewn to garments and furnishings. Among the approximately 150 silk fragments included by Martiniani-Reber in the catalogues of the Louvre and Musée des Tissus collections, more than half show evidence of being sewn to garments as trimmings along the sleeves, collar, breast, or elsewhere.[179] Silk yarns were also combined with other materials to provide a decorative effect or to imitate whole silks.

In addition to new finds, better excavation and recording methods have improved the quantity and quality of contextual information. Careful analysis of evidence from rubbish pits

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[174] Linscheid 2007, 91; also, see Linscheid 2012, 343-350.
[175] Linscheid 2007, 93.
[176] Linscheid 2007, 93-95.
[177] Linscheid 2007, 93.
[178] Linscheid 2007, 95-96. See glossary in appendix 1.2 for definition of twist.
[179] Martiniani-Reber 1986; Martiniani-Reber 1997; see Schrenk 2006, 29.

at Mons Claudianus demonstrated the extended life cycle of textiles.[180] As objects wore out or became damaged, they were remade for other purposes.[181] When reduced to a fragmentary state, textiles of all types were reused as padding and matting or recycled into felt.[182]

For textile artefacts containing silk, wear patterns provide a way to distinguish elite goods from worn and recycled materials. Analysis by researchers at the Louvre indicate that silk trimmings were removed from old garments and applied to new or refitted pieces.[183] An in-depth study of finds from the tomb of Thaïas, famously excavated by Gayet during 1900-1901, dated the burial to the second half of the seventh century.[184] Contrary to Gayet's description of rich costume, the garments were made from mended, ordinary cloth and embellished with coloured stripes and silk bands, apparently recovered from older textiles.[185] Radiocarbon dating suggests that the silk was produced approximately one to two hundred years earlier than the tunic to which it was attached.[186] The conclusion drawn from this analysis is that recycling of decorations was probably common and that fragments need to be interpreted individually as well as part of an ensemble.

Re-analysis of textiles and artefacts recovered from old excavations has yielded a surprising amount of new information concerning usage, not only for funerary purposes, but also as evidence for domestic and work place contexts. Re-evaluation of textiles from Schweinfurth's excavations at Arsinoe helped to clarify function, chronology, and usage habits.[187] Interpretation of the Karanis textile finds in terms of their archaeological context has

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[180] Mannering 2006, 149-159.
[181] See Mannering 2006; Wild 2006.
[182] Cardon, Cuvigny, et al. 2011, 52-53.
[183] Bénazeth 2006.
[184] Bénazeth 2006, 80.
[185] Bénazeth 2006, 80; see costume description in Gayet 1902, 55-58.
[186] Bénazeth 2006, 82.
[187] Fluck 2006.

revealed the convergence of domestic economies and religious rituals.[188] Surveys of material found in particular geographic regions over time provide a much-needed synthesis of information about scattered remains.

Excavations around the Mediterranean have led to identification of textile processing activities. Recent publications describe archaeological evidence for fulling, heated dye works, shell mounds, funerary markers, and stele.[189] Wild also published a summary of earlier finds.[190] However, despite some speculative interpretations that have been carried forward in the literature, we have no direct archaeological evidence of professional silk workshops sites or artefacts that can be reliably attributed to the production of complex weave textiles.[191] Wild's research on Roman loom technology points the way toward development of two beam horizontal looms, but evidence is far from conclusive.[192] Similarly, recent interest in the application of a '*zilu*' vertical type of loom for weaving wide width textiles is an appealing idea, but is supported only by reference to modern ethnographic observations.[193]

Unlike looms and implements, evidence of professional workshop production has survived in the form of papyrus illustrations. Stauffer published a detailed study examining use of illustrations in workshop settings.[194] Two distinctive types of illustrations can be distinguished from the evidence. Pattern books apparently provided a general iconographic repertoire to be used in various combinations for representation in different kinds of media.[195]

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[188] Thomas 2006.
[189] For example, see the papers included in Alfaro Giner, Wild, et al. 2004, in particular, Macheboeuf, C., 137-143; Wilson, A. 155-164; Ramon Torres, J., 165-174; Costa, B. and Moreno, I.S., 175-193; Alfaro Ginner, C. and Tébar Megías, E., 195-210.
[190] Wild 1970, 39-40 and Table H.
[191] Carroll 1985, 171; Wild 1987.
[192] Wild 1970, 75-78; Wild 1987.
[193] See Thompson and Granger-Taylor 1995-1996; Desrosiers 2004, 21-22; Ciszuk 2000.
[194] Stauffer 1993; Stauffer 2008.
[195] Whitehouse 2007, 297.

As reference guides, pattern books likely contributed to the wide dispersion of common design forms, both geographically and over time.[196]

Cartoons, the second type of illustration, provided a 1:1 scale guide for weaving tapestry textiles and were not suitable for drawloom preparation. However, the existence of purpose-specific illustrations suggests that a similar set of visualisation tools may have existed to draft a lifting plan and to provide a guide for tie-up of figure harnesses.

Radiocarbon analysis has become an increasingly important tool for dating organic historical materials including textiles. The basis for the test is the deterioration rate of 14C, an unstable isotope in the atmosphere absorbed through photosynthesis and propagated through the food chain.[197] Initially developed in the 1940s, radiocarbon measurements were performed on a group of authentic and suspect Persian 'Buyid' silks in 1973 with inconclusive results.[198] Current testing methods now rely on accelerator mass spectrometry (AMS) with the advantage of requiring smaller samples. Because of fluctuations in radiocarbon levels over time, measured results must be calibrated according to a scale based on dendrochronology. Measurements performed on materials dated to the first millennium have a degree of uncertainty of approximately one century.[199] To narrow this gap, results are normally reported within one (68.2%) or two (95.4%) standard deviations.

Based on experience gained from radiocarbon-dating more than 130 textiles in the Katoen Natie collection, De Moor has shown that the best results are obtained by analysing

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[196] Whitehouse 2007, 297.
[197] For a explanation of radiocarbon dating methods applied to historic textiles, see De Moor, Strydonck, et al. 2004; Strydonck 2007.
[198] Blair, Bloom, et al. 1992, 11.
[199] De Moor 2007, 100.

groups of similar or related textiles.[200] In one study, a group dating methodology was applied to selected Akhmim silks sharing a candelabra tree pattern, a motif common to a significant population of silks in a number of different collections. According to conventional representational analyses, these silks were classified into organic and stylised subgroups with the latter presentation attributed to a later period. Radiocarbon analysis of ten silks from three different collections dated the textiles between 687 and 828 with a statistically negligible difference in dating intervals.[201]

In another example of radiocarbon dating analysis, an intact tunic in the Katoen Natie collection was dated between the eight and tenth centuries. The design and decoration of this artefact closely resembles a tunic portrayed in a fourth-century mosaic now housed in the Trier Landesmuseum.[202] Collectively, these studies demonstrate the limitation of dating patterned textiles on the basis of iconography and style alone.

At the present time, the number of radiocarbon-dated textiles is too few to develop a reliable chronology.[203] A website database project to collect and share radiocarbon data is hosted by Rheinische Friedrich-Wilhelms-Universität in Bonn.[204] Recently, the Smithsonian Institute announced development of a new method of dating silk based on measurements of amino acid decay.[205] As compared with AMS, the new method is described as requiring a smaller sample size and faster results with less preparation of the material.[206]

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200 De Moor, Schrenk, et al. 2006; De Moor 2007.
201 De Moor, Schrenk, et al. 2006.
202 De Moor, Verhecken-Lammens, et al. 2008, 96.
203 De Moor, Verhecken-Lammens, et al. 2008, 96.
204 Schrenk 2009.
205 Moini, Klauenberg, et al. 2011.
206 Moini, Klauenberg, et al. 2011, 7578.

Dye analysis provides an additional tool for objective characterisation of attributes. Chemical identification gives information about the dyeing process and the nature of the stuffs used. The conventional view is that dye analysis alone is limited as a tool for attribution because stuffs were important trade commodities in their own right. However, Verhecken combined dye analysis results from 422 textiles to deduce a chronological order for the introduction and use of specific materials in textiles attributed to Egypt.[207] During the past two decades, progress has been made in the field because of improvements in analytical methods such as high performance liquid chromatography and photo diode array detection.[208] By examining degradation phenomena of dye stuff materials, it is possible to identify the original colour of a textile.[209]

Although silkworm varieties differ, cocoon rearing and handling practices as well as environmental factors have a large impact on the quality of the silk produced.[210] Once the sericin gum has been removed, the amino acid composition of silk fibroin does not vary among different strains or varieties.[211] As a result, there does not appear to be a way to 'type' silkworms based on de-gummed finished materials, for either historical or contemporary textiles. A recent study of wool materials used strontium in the wool to determine sheep rearing location.[212] A topic for future investigation is whether trace element studies of silk proteins could yield similar information.

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207 Verhecken 2007.
208 Hoffmann-de Keijzer, Bommel, et al. 2007, 214.
209 Hofenk-de Graaff and Roelofs 2006, 48.
210 Currie 2001, 11-23.
211 Becker, Magoshi, et al. 1997, 27.
212 Frei, Frei, et al. 2009.

5.8 Research Environment

A significant obstacle to Byzantine silk research is the lack of information about surviving fragments. No comprehensive international census of figured silks has been published to date for reasons that include the wide dispersion of material among collections, problems of definition, and the fact that fragments were divided in antiquity, at the find site, or in the hands of collectors. Between the 1930s and 1950s, Dumbarton Oaks undertook a census of Byzantine textiles in North American collections. Never published, this special collection consists of 2,500 black and white photographs and includes a card file documenting each object.[213]

In 1994 Muthesius published the most comprehensive cross-collection survey to date of fragments mainly found in shrines and provisionally attributed to Byzantine workshops on art historical grounds. This handlist consisting of 1,400 silks is important, but lacks specific technical information necessary for comparative analysis. Such a resource needs to be expanded and maintained in a more dynamic form to include the fragments held in undocumented collections as well as new finds and revisions.

Collection and exhibition catalogues provide another resource for study, but are typically intended to demonstrate connoisseurship or to illustrate particular thematic or historical perspectives, so are seldom comprehensive. Few contain even the basic technical details necessary for comparative analysis. A growing number of institutions are putting collection images on-line, a development that dramatically expands access for scholars and the general public. While helpful for representational analysis, few images provide sufficient resolution to study technical details.

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[213] Dumbarton Oaks 2012; Columbus 1968, 9.

The most significant problem pertains to collection documentation. Only a small fraction of silks have been analysed and recorded according to current accepted standards. Most collections were assembled in short bursts between 1900 and 1930. At the time, no consistent vocabulary existed to describe particular technical attributes. If textiles were studied at all, curators applied their own terminology and methods. Different descriptions by successors have resulted in inconsistent references, even within the same collection.

At the present time, scholarly interest in historical and archaeological textile research is demonstrably high with well-attended conferences and lectures. Despite research progress in some areas, not all segments of the field have advanced in recent years. In particular, conservation standards and resource constraints at publicly funded museums have sharply reduced research access to collections.

Given the fragility of textile artefacts and their vulnerability to damage from exposure and handling, strict conservation standards are vital to preserve materials for future generations. Most institutions have implemented formal policies specifying conditions for supervision, handling, note-taking, and photography. The practical consequence is that investigative methods must be strictly non-interventional with only short intervals allowed for first-hand study.

Higher conservation standards and limited staffing resources at museums means that researchers must alter customary investigative methods as described here by Wild:

> The analyst is primarily interested in adding to knowledge, and he or she may not be overawed by the intrinsic worth of a textile in a museum context. The analyst cannot just look: he or she must be able to handle (gently!) and poke, to establish a weave's structure or the form of a damaged or heavily felted selvedge…. So

> whatever the conservation technique employed, access to the back of the textile and its edges ought to be easy.[214]

While some types of textiles can be analysed through non-interventional methods alone, the scale of fine compound weave silks requires magnification and use of a probe to observe structural details and to document features over a measured distance. Consequently, apart from textile professionals at their home institutions, few researchers have the opportunity for thorough first-hand investigation of figured silks. Even if physical access is permitted in certain instances, a significant number of valuable silks have been mounted in ways that make observation of the reverse side difficult or impossible.[215]

During the past two decades, structural changes in the management and presentation of museum collections has had a major impact on textile studies. Most institutions now define curatorial roles on a regional basis rather than by particular classes of objects, a trend that has reduced the number of textile professionals at museums. To attract visitors, institutions now focus on exhibitions and publications rather than research. At some institutions where resources are especially tight, large textile collections built up on the heels of the antiquarian era now languish.

Even at well-resourced institutions, there is little opportunity for incomplete or antiquated collections documentation to be updated. Few curators have the expertise and resources necessary to perform detailed, piece-specific technical analyses. Computerisation of records has preserved what little provenance information might exist, but also carried forward long out-dated attributions. The large scale of most collections, limited resources, and

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[214] Wild 1990, 3-4.
[215] See chapter 7.1 for data concerning access to the reverse side of a textile.

specialised knowledge required to interpret new scholarship makes documentation an on-going challenge for most museums.

Financial challenges and resource constraints have not affected all public institutions equally, and textiles studies at several continue to thrive. But it is now specialised private museums that lead the research agenda in the field. During the past half century, the broad shift in textile manufacturing away from former industrial centres on the one hand, and the decline of affiliated textile clubs on the other, means that museums no longer have a constituency of visitors with professional knowledge or informed appreciation of textile arts. Few textile researchers now active in the field have had sustained experience with complex weaving structures in the manner of Flanagan, Guicherd, Vial, and Becker. In summary, a fundamental and on-going challenge for textile professionals will be to demonstrate the relevance of weaving technologies to the interpretation of economic and social history. It is this conclusion that has led me to define my research objectives for this study of figured silks.

5.9 Research Objectives

In summary, research concerning historical silks is based on a coincidence of two phenomena: special climatic conditions that permitted organic matter to survive in a relatively intact state, and a set of cultural, social, and political circumstances that enabled a large body of material to be transferred from find contexts into the hands of collectors, and eventually concentrated in European and North American museums.

The majority of silks now in public collections were found in Egyptian graves between 1880 and 1940. Other sources, also lacking in contextual information, include cemeteries in the Near East and European shrines. Analysis of surviving fragments shows that many silks were cut into pieces in antiquity where they were applied to garments as ornaments and trim.

Related pieces were also divided post-excavation and are now scattered among hundreds of collections.

The form and circumstances through which silks were gathered into collections have shaped scholarship and research approaches over time to the present. Initially, collectors valued figured silks as examples of ornamental design. As art historical methods evolved, figured silks provided a rich body of material for iconographic and stylistic evaluation. To date, representational analysis is the dominant means of attributing silks to particular cultures and time periods.

Although research based on weave structure analysis progressed from the mid-1900s onward, problems of access and resources during the past two decades have left the field with few participants actively involved in technical studies of figured silks. Improved technologies including radiocarbon dating and dyestuff analysis provide important complementary sources of information, but require destructive testing and are relatively expensive. In summary, the field lacks a well-defined research agenda for figured silks and an organisational framework to implement such a programme.

While a comprehensive strategic plan to revitalise research in the field is beyond the scope of this work, intermediate steps to overcome obstacles to technical analysis are possible now. A first objective is to develop a conservation safe approach to document a representative cross-section of silks from various collections. A second goal is to investigate how the CIETA method of technical analysis can be adapted to interpret technical attributes based on a series of high-resolution digital photo images. The following chapter defines a research methodology to satisfy these objectives.

PART II: CHAPTER 6 - COMPUTER VISION RESEARCH METHODOLOGY

The rationale for selecting weft-faced compound weave figured silks as the subject of this study goes beyond the fact that they were historically important and provide valuable representational evidence. The work involved in producing these complex structures increased the number of decisions involved in the process and required more planning and specialised skills. Over time, efforts to overcome process problems spurred development of new methods and technologies. Managing and manipulating thousands of fine silk yarns was an error-prone process, and we gain evidence from successful and flawed executions. Collectively, surviving textiles from this group convey decision and production information for characterisation and analysis purposes.

This chapter opens with a description of the technical attributes common to weft-faced compound weaves. The aim is provide an overview of how pattern, weave structure, and technology developed synergistically over time. While not all processing steps involved in weaving weft-faced compound structures convey evidence that can be interpreted using visual inspection alone, high resolution digital imaging and computer vision tools provide new methods for more intensive examination of evidence than is possible with conventional methods.

Development of a research methodology for figured silks requires definition of an analytical framework appropriate to the nature of the evidence as well as selection of investigative tools. I defined a set of specifications to distinguish technical characteristics among superficially similar textiles and to document decisions involved in the production process. Developing this project from specifications into a functional application required various resources including access to textiles, specialised equipment, and software development. The resulting methodology was applied to collect data from a representative cross-section of historical silks.

6.1 Pattern, Weave Structure and Technology

In historic textiles studies, the fact that a fabric contains repeating designs is not in itself significant. Highly complex textiles have been woven throughout history in various cultures on simple looms using only manual methods for warp selection.[1] As in other craft occupations, the main requirements are time and skill, resulting in unique works. Among historic textiles attributed to the Mediterranean and Near East, we have many examples of fine patterned tapestries that were created through a process that was slow and tedious.[2] A major theme in historical textile studies is the progressive development of improved methods for pattern reproduction.[3] Over time, professional workshops sought to reduce the time and labour involved in weaving patterned textiles, combining methods and equipment to produce a greater quantity of materials figured with repetitive designs.

An important technical development was the adaptation of textile structures for pattern weaving. In textiles woven with a single warp and weft, yarn interlacement is coincidental with the design as in tapestry weaves.[4] For loom-patterned textiles, introduction of a supplementary pattern weft bound by a regular sequence of warps produces a decorative effect independent of the ground weave. Excavated linen fragments from Egypt include examples of both continuous (selvedge to selvedge) and discontinuous ('brocaded')

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[1] Many general weaving histories contain illustrations of complex textiles woven on simple looms. See for example, Harris 1993; Jenkins 2003.
[2] For a well-illustrated volume containing many colour images of various types of tapestry weaves, see Schrenk and Knaller 2004.
[3] For example, see Geijer 1979; Becker 1987.
[4] Grosicki 2004, 1.

supplementary pattern wefts.[5] A few researchers have published analyses of early forms of supplementary weft-patterned tabby silks.[6]

Development of compound weaves represented a major advance in patterning technology. In a compound structure the warp or weft is divided into two or more series, each with an independent function.[7] As a result, a compound woven design is independent of its interlacing structure.[8] Compound structures are either warp or weft-faced. The warp-faced compound weaves typical of Han Chinese silks have two or more warps separated by alternate weft passes.[9] Only one warp appears on the face; the other is pushed to the reverse.[10] In this structure, warp floats cover all weft passes. Figured patterns are formed by the movement of warp floats from the surface to the reverse side or interior of the textile.[11]

The weft-faced compound textiles characteristic of Near East and Mediterranean workshops applied a similar principle to pattern formation, but with the roles reversed between warps and wefts in surviving fragments.[12] Two warps are required for this structure: binding and main. These are tied onto the loom in alternating order, typically in constant proportion. Weft-faced compound weaves have a minimum of two complementary wefts, but complex polychrome designs may have five or more different colours.[13] Patterns are formed by the relative position of the main warp, which moves the weft from the face to the reverse side or interior of the textile. The distinctive structural feature of this weave is the

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[5] Kendrick 1920, 76; Becker 1987, 133-134.
[6] For example, see Granger-Taylor 2000; Granger-Taylor 1989; De Jonghe and Tavernier 1978.
[7] CIETA 2006, 11.
[8] Grosicki 2004, 1.
[9] For technical studies of Han Chinese warp-faced compound weave structures, see Burnham 1965; Burnham 1971.
[10] CIETA 1987, 42.
[11] CIETA 1987, 42.
[12] CIETA 1987, 26-27.
[13] CIETA 1987, 26.

arrangement of weft floats to hide the warps below the cloth surface. The structure of taqueté and samite are illustrated in the diagrams presented on appendix 6.1.

Development of compound structures altered both the characteristics and appearance of patterned textiles. Textile performance is a subject seldom addressed in historic studies. In comparison to tapestries, compound weaves have a number of advantages. The sensory qualities of the smooth silk surface and supple drape differed greatly from cloth woven from other fibres.[14] The mechanical properties of silk combined with the close spacing of warps made for a stronger and more durable fabric that was capable of withstanding wear. The continuous weave structure made the material suitable for tailoring and provided a foundation for applied decoration.

In a tapestry structure, patterns are formed by the manipulation of individual warps.[15] Weavers freely apply effects such as shading and curves, producing designs that are not defined by the grid structure imposed on loom patterned textiles. The subtle shading effects characteristic of fine tapestries are found very rarely in compound structures.[16] Lacking a structure suitable for blending, most historical Mediterranean and Near East patterned silks display sharp colour contrasts.[17] The loom controls patterning, so design elements are restricted to a rigid grid formed by the right angle intersection of warps and wefts.[18] Workshop designers had to decide how best to adapt pattern outlines to the fixed spacing imposed by main warps.[19] Other design considerations included orientation, scale, and

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[14] Drape is a fabric characteristic that refers to the way a textile falls over a three dimensional form. See Kadolph 2007, 24-28.
[15] For an illustrated overview of tapestry weaving techniques, see Burnham 1980, 144-150.
[16] See Martiniani-Reber 1997, 11; Schmedding 1978, 19-20.
[17] See chapter 7.4 for pattern characteristics pertaining to colour use.
[18] CIETA 1987, 16-18.
[19] For grid based textile design principles, see Grosicki 2004, 211-248.

balance. To a large extent, the appearance of pattern designs for weft-faced compound weaves is determined by the technology of production.[20]

One characteristic feature of many surviving weft-faced compound weaves is the relatively large scale of figured patterns in relation to the incidence of repetition. An arrangement of motifs is combined into a defined pattern unit as the basis for design repetition throughout the textile.[21] To accommodate the structural limitations of a loom, a pattern repeat must be squared off so that the sides are parallel with warps and the top and bottom are parallel with the wefts.[22] Looms can only create repeats in two ways: straight and pointed.[23] In a straight repeat, a pattern unit is duplicated side by side without variation. A point repeat design reverses on itself, expanding the size of the visual unit through horizontal or vertical symmetry or a combination of both.[24]

According to CIETA terminology, an additional characteristic of weft-faced figured weaves is the use of a memorising system for the repetitive selection of warp ends to form a woven pattern.[25] Other forms of weaving may contain repeating patterns, but are not considered to be figured designs because warp ends are manipulated manually with each pass of the weft.[26] A range of devices can be used to record sets of warp ends in sequence for pattern formation. A simple approach is to place a series of pattern rods directly into the warp behind the binding shafts.[27] Each rod represents a pre-selected set of warp ends comprising one row of a pattern. As weaving progresses, pattern rods are lifted in sequence to form the

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[20] Washburn 1988, 47.
[21] CIETA 2005, 17.
[22] Sonday 1987, 58.
[23] Sonday 1987, 58.
[24] CIETA 2006, 29, 36; For analysis of symmetry in continuous compositions, see Washburn 1988, 40.
[25] CIETA 1987, 16.
[26] CIETA 1987, 16.
[27] CIETA 1987, 16.

recorded design. A loom equipped with a large number of shafts, each dedicated to a set of main warp ends corresponding to a pattern row, operates in a similar way, but without the need to replace the pattern rod in the warp.[28]

While repeating designs can be woven with shed sticks or dedicated shafts, there are practical and physical limitations to pattern scale with these methods. The drawloom developed over time as a means to organise and manipulate main warps, either in groups or individually.[29] By definition, a drawloom contains two sets of harnesses: a binding harness comprising shafts to manipulate binding warps, and a figure harness to control the warp for pattern formation.[30] A dedicated figure harness provides the independent memorising system necessary for consistent repetition of large scale figured patterns. From a modern point of view, the capability to store sequences of mechanically recorded work steps means that tie-ups were, in effect, an early form of software.

The evidence provided by a number of surviving wool taquetés demonstrates that sequenced pattern weaving methods became widespread between the fourth and seventh centuries.[31] During this interval, drawloom technology developed and became more widespread.[32] Various strategies evolved to expand the resolution, scale, and efficiency of weaving patterns. These included enlarging the scale of patterns with multiple warps and expanded use of horizontal and vertical symmetry in design.

According to the accepted historical progression most recently presented by Desrosiers, compound weaving technology continued to evolve with new patterning methods emerging in

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[28] CIETA 2006, 7.
[29] Becker 1987, 253-270.
[30] CIETA 2006, 17.
[31] Verhecken-Lammens 2007.
[32] For a historical overview of technical developments, see Geijer 1979, 97-102; Becker 1987, 253-270.

the tenth to eleventh centuries.[33] The development of monochrome patterned silks is considered to be one such adaptation, described by some analysts as a reaction to coloured designs.[34] Instead of high contrast colours, monochrome patterns were produced by textural effects to display patterns.[35] Incised monochrome silks applied the same structure and tie-up as samites, but were patterned by the arrangement of the small apertures formed by the exchange of complementary wefts.[36] Flanagan and Becker have demonstrated how a 'pseudo-damask' structure was derived from samite.[37]

During the twelfth to thirteenth centuries, advances in weaving technology led to development of true lampas.[38] Lampas integrates elements of a plain or twill ground with weft patterns into a single cloth comprising contrasted structures. A figured pattern is composed of weft floats tied by a binding warp in combination with a ground fabric formed by a main warp and weft.[39] Unlike weft-faced compound weaves, main warps are visible and the weave is balanced. Surviving fragments suggest a number of intermediate steps linking weft-faced compound weaves to the development of lampas. An important innovation described by Granger-Taylor was dual control of a selected set of warps in both the figure harness and binding shafts.[40]

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[33] For example, see Desrosiers 2004, 23; Schorta 1997.
[34] Becker 1987, 118.
[35] Schorta 1997, 173. See chapter 4.4 for monochrome pattern weaves.
[36] Becker 1987, 118.
[37] Flanagan 1956, 498 n. 2; Becker 1987, 120-129. Monochrome pattern structures are described by names including pseudo-damask, proto-damask and proto-lampas, depending upon specific structural attributes. See Schorta 1997; Granger-Taylor 2000. For an extensive analysis see Schorta 2001.
[38] Schorta 1997.
[39] CIETA 2006, 23.
[40] Granger-Taylor 2000, 31.

Development of true lampas proved to be a major advance in weaving technology.[41] The structure was flexible and versatile, providing a repertoire of patterning choices that could combine colour, texture, light effects, and materials in complex and sophisticated cloths at weaving centres throughout the region.[42] Although it is possible that lampas was first woven on the same looms as weft-faced compound weave silks, the equipment was adapted to weave the structure more efficiently.[43] The shafts associated with the main and binding warps were both operated by a single weaver.

While the earliest weft-faced compound weaves in the region were made of wool, advances in complex weaving technology relied upon the superior mechanical properties of silk. As compared with other natural fibres, silk is unique for both for its tensile strength and elasticity. Tensile strength refers to the ability of a fibre to resist stress.[44] Tenacity is a measure of the strength of a fibre and measures the force at which the fibre breaks.[45] As shown on tensile property chart in appendix 6.2, flax and cotton have high tenacity, but rupture with application of additional force. Wool has low fibre tenacity, but is more elastic than vegetal fibres. Initial modulus measures resistance to extension as an indication of fibre stiffness.[46] Both flax and cotton initially resist extension, but break with additional stress. Yield stress measures the limit of a fibre to be extended and recover elastically without permanent deformation.[47] Silk is capable of withstanding significantly higher rates of stress than wool. The area under the stress-strain curve in appendix 6.2 shows the relative

[41] CIETA 1987, 29-33.
[42] CIETA 1987, 29-30.
[43] CIETA 1987, 30.
[44] Kadolph 2007, 28.
[45] Kadolph 2007, 28.
[46] Lewin and Pearce 1998, 439.
[47] Lewin and Pearce 1998, 439-440. For an explanation of microstructural properties concerning silk fibres, see Garside and Wyeth 2002; Wyeth 2005.

performance of natural fibres by this collective set of measures. The curves demonstrate silk's superior properties to withstand high loom tension.

On average, silk filaments may be between 900 and 1200 meters long, although lengths may have been shorter in antiquity.[48] In terms of diameter, silk is the finest fibre with an average width of 9-12 micrometres as compared with 10-50 for wool, 12-16 for flax and 16-20 for cotton.[49] Fine fibres make a textile more pliable with better drape.[50] Among textile fibres, silk exhibits a higher capacity for dye absorption.[51] As a protein, silk can be coloured with a wide range of dye stuffs including those based on acids, bases, and metal salts.[52] Silk also absorbs dyes at lower temperatures than wool.[53]

The mechanical properties of silk are enhanced when filaments are consolidated. To be suitable for textile production, silk must be processed into yarn.[54] Yarn is defined as an assemblage of fibres twisted or laid together to form a continuous strand suitable for textile applications.[55] While fibre is important in determining the characteristics of a textile, the type and structure of yarn also has a significant effect on appearance, texture, and performance.[56] Consequently, both the inherent properties of silk and the choice of yarn structure have bearing on textile construction. Unlike staple fibres, which need to be spun to form yarns, the

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[48] Mauersberger 1954, 23.
[49] Kadolph 2007.
[50] Generally fine fibres produce softer drape than course fibres. See Kadolph 2007, 24-28.
[51] Mauersberger 1954, 724.
[52] Ullmann 2008, 400; Lewin and Pearce 1998, 449-452.
[53] Mauersberger 1954, 724.
[54] Thread is defined as any continuous strand, single or compound, made from any fibre or filament. Yarn refers specifically to thread prepared for weaving or knitting. See CIETA 2006, 38, 44.
[55] Mauersberger 1954, 32.
[56] Kadolph 2007, 20-21.

filament structure of silk means that the yarn does not stretch under tension because of fibre slippage.[57]

Depending upon the fibre and desired textile characteristics some yarns were plied. Plying combines two or more single yarns into a compound structure to improve balance, evenness, strength, and appearance. Most Mediterranean silks are constructed from single yarns. Plied silk yarns were rarely used for weaving except in cases when spun floss required additional strength.[58]

Twist describes the process of rotating a strand of fibres about its axis to form a yarn and to improve strength and elasticity.[59] As the active element in weaving processes, the warp is subject to the most stress and wear. In weft-faced compound weave silks, warp yarns are almost always twisted to resist abrasion, fatigue, and other types of stress-related damage.[60] In the closely set warps used to weave silks, abrasion resistance is an important attribute to reduce yarn wear and breakage. Twist varies in two ways: the direction in which fibres are twisted and the amount of twist over a given length of the yarn. Twist is inserted by rotating fibre strands in either a clockwise (Z) or anti-clockwise (S) direction in relation to the fibre axis (appendix 6.3).

Surviving material shows that for drawloom woven silks to be executed successfully, a series of controlled processes was necessary. Each silk yarn component had to be appropriate for its purpose and maintain a certain degree of consistency throughout.[61] Uneven twist caused breakage in the warp, requiring repair, and disrupted the production process.

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[57] For discussion of fibre slippage in yarns, see Fannin 1998, 13-15.
[58] For the definition and significance of silk floss, see chapter 4.2.
[59] Booth 1968, 229; Hudson, Clapp, et al. 1993, 160.
[60] Hearle, Grosberg, et al. 1969, 64.
[61] Mauersberger 1954, 697.

Inconsistent yarn diameter and defects such as slubs and knots marred textile appearance. For patterns to be replicated consistently, warps and wefts had to maintain uniform spacing, without evident warp draw-in or inconsistent force applied to beating-in wefts. To produce a quality figured textile, patterns had to be appropriate for the loom on which they were woven.[62]

From an organisational standpoint, drawloom technology had a major impact on production methods and work processes. Memorised pattern reproduction represented enormous work savings in shed selection, but required a significant investment of time to tie-up the pattern harness. Drawlooms permitted faster production of complex figured cloths in greater quantities than was possible with other production methods. One of the characteristics of professional textile workshops is specialisation of work.[63] With the advent of drawlooms, work steps formerly performed by individual weavers were disaggregated and adapted to specialised functions. On a drawloom, the weaver managed the binding warp, which was divided among a series of shafts, while an assistant manipulated the draw harness in a defined sequence to form the intended pattern.[64] The implication is that coordination and control had to be maintained in order to produce a high quality silk.

6.2 Imaging and Computer Vision

From a technical point of view, silk fragments can be interpreted as the product of a series of processes combining raw materials and labour into manufactured goods. Woven line by line, textiles can be examined as a sequential production record. The problem is that evidence is carried along as low-level details that require measurement methods to

[62] Bellinger 1961, 1-3.
[63] Muthesius 1989a.
[64] CIETA 1987, 26.

accumulate and analyse data. The challenge is to find a method to discern technical details and define relationships among sets of distinguishing characteristics.

To access the information contained in historical materials, researchers have considered methods from textile material science to measure properties and appearance such as fibre and yarn thickness, warp tension, fabric density, texture, evenness, and weave defects.[65] The drawback is that some characterisation methods rely on destructive tests that are unacceptable for rare and fragile archaeological materials. As an alternative, some textile specialists have experimented with non-destructive photographic imaging techniques as a means of gathering data.[66] In recent years, dramatic advances in digital imaging have created new opportunities for objective characterisation with conservation safe methods.

The research programme presented here combines digital imaging with use of computer vision software tools for analysis. Within the field of computer engineering, computer vision refers to technologies associated with acquiring, processing, analysing, and understanding information from digital images, specifically utilising principles of the biological vision system.[67] In imaging applications, the goal is to infer attributes of the physical world from two-dimensional digital representations.[68] In practice, the field extends from low-level image processing to higher-level knowledge. Image processing methods were first applied to textile manufacturing in the 1960s. Since that time, imaging technologies have become predominant

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[65] El-Homossani 1988; Cooke and El-Gamal 1990; Cooke 1990; Cooke and Peacock 1992; France 2005.
[66] El-Homossani 1988; Cork, Cooke, et al. 1996; Bischoff and Murray 2005.
[67] Nalwa 1993, 3-29.
[68] Sonka, Hlavac, et al. 2008, 12-13.

in industrial textile quality assessment with specialised systems for inspection of fibres, yarns, fabrics, and finished goods.[69]

As compared with conventional methods for studying historical textiles, computerised image analysis has a number of benefits. Automated processing dramatically increases both the accuracy, and number of possible measurements. Data describing defined textile attributes are available in a form and quantity appropriate for application of standard statistical methods. Furthermore, digitisation and storage enable image recording to be separated from detailed analysis, using the limited time available for *in situ* textile observations to best advantage.

Going beyond the speed, accuracy and convenience benefits associated with automation, digital imaging enlarges the basis for textile analysis by making new information available for consideration. Image analysis effectively extends the limits of normal visual perception, enabling detection and measurement of characteristics too subtle or difficult to measure with conventional, non-automated methods.[70] High quality digital images photographed according to an explicitly described protocol including use of a scale with divisions appropriate for measurements provides a basis for objective analysis in a form that can be shared among researchers. Data management systems provide an additional tool to support textile characterisation.

6.3 Specifications for Attribute Characterisation

This research plan incorporates methods from textile material science and industrial inspection to characterise figured silks according to measurable attributes. Advancing the project to a stage suitable for application of computer vision tools required developing

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[69] Behera 2004, 172.
[70] Sonka, Hlavac, et al. 2008, 5.

specific measurement methods. To this end, I devised a set of sixteen tests grouped into four categories: material, textile, pattern, and errors as shown in appendix 6.4. Specifications for each test were developed according to a common framework comprising: test purpose and significance, defined inputs, step-by-step measurement methodology, measurement units, and results.

a. Material characteristics

Material characterisation evaluates the qualities of yarns as products of organised processes, comprising sub-assemblies for textile weaving. The expectation is that professional workshops used expertly prepared inputs with less variation than materials from a more casual settings. A survey of the textile history literature shows that few technical researchers go beyond fibre type identification to investigate the dimensional and structural characteristics of silk components.[71] At the outset of this project, I attempted to define a set of methodologies to study material characteristics on a hierarchical basis in terms of both yarns and fibres.

Two yarn measurements are included in this programme: diameter and surface helix angle. One of the goals of performing systematic yarn analysis is to discern specification evidence. From textile material science, we know that yarn size influences textile mechanical properties and appearance.[72] Yarn diameter is the cross-sectional width of the textile component and should remain consistent in a lengthwise direction. The two main factors contributing to diameter are: the number of fibres in cross-section and the amount of fibre compaction.[73] The yarn diameter test specifies a methodology to measure components reliably

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[71] Barnard 1972, 29.
[72] Kaswell 1953, 175; Lord and Mohamed 1982, 377; Morton and Hearle 1993, 129.
[73] Morton and Hearle 1993, 129.

and non-invasively. The helix angle test measures the relationship between surface fibres and the yarn axis when twist is applied (appendix 6.5). Based on measurements of randomly selected binding points, the degree of variation may provide an indication of process control.

Some researchers have attempted to use silk diameter measurements as a means to assign geographic origin. In his study of silk finds from Palmyra, Pfister presented a chart that attempted to correlate silk fibre diameter and weight measurements with geographic place of origin.[74] Separately, in a series of detailed studies, Nunome sought to determine chronological and geographical variation in East Asian silk.[75] Despite these attempts by Pfister and Nunome, two problems make their findings invalid for the purposes of dating and attribution. First, engineering studies of silk show significant intra-fibre diameter variation, a factor that has limited wider application of the material beyond textile use, despite its favourable mechanical properties.[76] Second, the methodologies applied by both Pfister and Nunome relied upon destructive physical sampling. For characterisation purposes, the number of possible measurements is too few to establish statistically valid findings.

However, some of Nunome's observations provide a basis for expanded study of historical silk fibre characteristics. His research suggested a general trend toward larger and more geometrically-shaped filaments over time.[77] Nunome also reported that finer fibres are more difficult to handle and require additional care and expertise in textile production processes.[78] Material science research suggests that thinner silk appears to have better

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[74] Pfister 1934, 39.
[75] Nunome 1992; Riboud 1981.
[76] For recent studies of silk fibre properties for engineering applications other than textiles, see Perez-Rigueiro, Viney, et al. 1998; Perez-Rigueiro, Viney, et al. 2000; Perez-Rigueiro, Elices, et al. 2002.
[77] Nunome 1992, 284.
[78] For example see Nunome 1992, 288.

mechanical properties because the microstructure is more compact with fewer defects and better crystalline orientation.[79]

Development of high-resolution digital microscopy has now made it possible to measure fibre diameter non-invasively and apply standard statistical methods. My original set of specifications included tests designed to measure fibre diameter and count surface filaments. Initial experiments showed that, while feasible, the equipment and procedures necessary to obtain reliable data are different from all other measurements included in this research programme. Consequently, comparative measurement of fibre diameter in intact textiles provides an opportunity for a future research project.

b. Textile characteristics

Tests in this category evaluate figured silks according to weave characteristics. Measurements provide an objective basis to assess the structural attributes independent of the particular design represented. While technical analysts often note weave structure decisions in their observations, my goal is to expand weave structure information for comparison among groups of textiles.

Data collection is based on a series of binding point-based measurements across the face of a textile. Warp and weft group densities are measured as average values. Warp group variations can be caused by several problems including warp draw-in, uneven yarn thickness, and loom setup. Inconsistent force applied to beating-in wefts distorts intended pattern proportions. The extent to which warps and wefts are evenly spaced provides an indication of

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[79] Zhao, Feng, et al. 2007, 680-683.

weaving control and a measure of relative quality. These data also provide a basis to estimate the implications of decisions such as shuttling sequencing and wide textile widths.[80]

c. Pattern characteristics

Analysis of 'Byzantine' figured silks provides additional information about the skills and equipment used to produce certain patterns. Technical design characteristics have a large bearing on appearance, but are rarely considered in representational analyses. Distinguishing characteristics include design symmetry, pattern orientation, information content, colour choice, scale, and resolution.

Tests in this category assess pattern unit dimensions in terms of weft and warp groups. A warp group comprises a binding warp and one or more main warps as a structural unit. Similarly, wefts that function as a set constitute a weft pass. Quantifying the relationship between the two components allows measurement of the area occupied by surface wefts for objective comparison of design resolution.[81] Variation among pattern units in the same or divided fragments indicates preparation or execution errors.

The design drafted for weaving must also be in conformity with intended equipment. Two equipment-related constraints are the physical dimensions of the loom and its pattern capacity.[82] Pattern unit data can provide evidence for loom characteristics because the planned number of pattern repeats had to fit within the weaving width of the loom.[83] The number of warp ends that can be independently controlled determines pattern capacity.[84] Although the appearance of looms used to weave weft-faced compound weave figured silks

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[80] See chapter 7.3 for work implications of weft shuttling order.
[81] This measurement is complementary to the warp and weft pattern step counts (*decoupure*) included in the CIETA dossier; see CIETA 2006, 13.
[82] El-Homossani 1988, 32.
[83] El-Homossani 1988, 31.
[84] Jain 1994, 53-54.

may be irretrievably lost, the measurements described here provide some specific information about how looms functioned and were operated.

d. Error characteristics

In studies of historical silks, mistakes can provide detailed information about production processes. Faults can be interpreted diagnostically to assess whether the problem occurred in the preparation or execution stage of production. Loom preparation errors include incorrect entering of binding warps in shafts, use of an inconsistent number of warps, tie-up of warps in the wrong harness, and pattern tie-up faults. Examples of execution problems are incorrect binding or pattern shed selection, inadequate warp tension, faulty weft insertion sequencing, lack of coordination between a weaver and assistant, and failure to keep warps evenly spaced. In some cases the root cause of a problem can be identified, giving specific information about equipment, material, and work practices. In other instances, the pattern of faults supports a broader picture of processes.

Software can assist in the detection of mistakes in both micro and macro scale images. Binding point tests can aid in the detection of faults stemming from loom tie-up mistakes or weaving execution errors. Although main warps are not regularly visible on the textile surface, the average distance between adjacent binding points can be used to detect main warp inconsistencies. Departure from the mean value may indicate areas where the ratio between main and binding warps differs from the average, indicating a tie-up error. An interruption in the regular system of binding points on the textile face may indicate a binding shed selection sequence error.

The computer vision application includes a tool for pattern matching as an aid for analysis. Based on a user-defined reference area, an overlay for pattern matching can be rotated or flipped for comparison purposes. The computer vision application indicates the specific location of differences to aid analysis. Mistakes that re-occur in pattern units vertically aligned in the warp direction may point to a main warp tie-up problem. A non-repeating mistake in a pattern unit may indicate a main warp selection error.

6.4 Project Development

While potentially valuable to historic textile research, development of a strictly non-invasive imaged-based system for comprehensive textile documentation proved to be a challenging task. As a new application for imaging technologies, the field lacks defined methods and specific experience relevant to this project. As a result, substantial work was required to devise research methods for data gathering and analysis. The quantity of data made possible by imaging and computer vision technologies called for careful development to ensure that measurements were meaningful and objective. Moreover, non-invasive data collection across a number of different institutions required specialised portable equipment and formalised procedures to ensure data consistency and comparability.

To overcome the technical and practical challenges associated with this project, I defined my work as a series of intermediate goals. This approach allowed me to acquire the experience and resources necessary to move forward through what eventually became five stages: 1) feasibility assessment, 2) methodology development, 3) equipment specification 4) definition of a formal image capture protocol, and 5) methodology testing and revision.

A major consideration in developing this project was the inherent variability of textiles as compared with other assembled materials. All textiles, even modern fabrics, are the product of various mechanical forces interacting in three dimensions, and are subject to deformation and skewing.[85] In addition to the normal variability associated with modern materials, ancient textiles survive in fragmentary and deteriorated states. Silks have been subjected to a wide variety of conservation treatments over time and are mounted in many different ways. Additionally, performing image capture *in situ* can introduce discrepancies due to differences in ambient lighting conditions and equipment setup.

In view of these factors, careful methodological design was important to ensure reliable, reproducible results. Modern materials with known yarn and textile characteristics provided a control for measurement purposes. To prevent distortion of results due to visible degradation, data were collected from the most intact areas of surviving fragments. Standard statistical techniques were applied to ensure that samples were representative. Closely defined procedures for equipment setup and image capture reduced the likelihood of inconsistent measurements.

The source of data for my project was a series of high-resolution digital images. Finely woven silk textiles must be photographed at high magnification to show yarn evidence and to measure construction details. To obtain such images, I needed three sets of resources: 1) access to a textile collection with a representative selection of silks within the parameters of my study, 2) equipment suitable for *in situ* image capture, and 3) a defined image capture methodology. During the course of my work, I found that I had to approach these resources collectively in order to balance technical and practical limitations in one area against capabilities elsewhere.

[85] Lord and Mohamed 1982, 138-139.

a. Resources: textiles

After defining an initial project scope, I first examined how digital photographs could be used to study technical production details. Weft-faced compound weave textiles consist of two sides bounding an interior warp layer obscured by surface weft yarns. Manipulation of these hidden warps determines the appearance of the figured pattern. The two-part question at hand was whether a sufficient number of technical details could be determined from the textile face alone, and if so, would these attributes be visible and meaningfully represented in two-dimensional photographic images?[86] My specific goal was to observe textile characteristics such as material components, weave structure, and design features.

To define how computer vision might be applied for characterisation and analysis, I needed to obtain high-quality photographic images of textiles. Finely woven silks must be photographed at a magnified scale to show construction details. After searching published sources, I found few photographs of sufficient quality to observe technical attributes. Although catalogues and published analyses typically include images, these mainly illustrate textiles at a macroscopic scale with little discernable detailed evidence visible. Many authors use diagrams to describe technical details.[87]

Thanks to the support of the staff at Dumbarton Oaks, I photographed seventeen weft-faced compound weave textiles in the collection. On my first visit, I obtained a study population of 3,400 images at micro and macroscopic scales in order to develop my methods.

Based on work accomplished in this stage, I concluded that a research methodology using digital images of the face side of mounted textiles photographed *in situ* at various

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[86] For a discussion of image representations in computer vision, see Sonka, Hlavac, et al. 2008, 12-13.

[87] For example, see Verhecken-Lammens 2000.

institutions would provide objective and specific data for textile analysis. While a non-interventional approach limited to the textile face does not allow for access to the reverse side of the fabric, an image based-methodology could provide the basis for extensive analysis, including some features not measured or quantified by conventional analytical methods.

As my research advanced, I needed to test different equipment and image capture options. This process required controlled experimentation to define a set of variables to meet my imaging needs.[88] For this purpose, I gathered a small study collection of taqueté and samite materials comprising archaeological silks, reproductions, and new materials woven by specialist handweavers. As a final step before proceeding to the actual data collection phase of my project, I returned to Dumbarton Oaks to test my methods and software.

b. Resources: equipment

This project required equipment capable of capturing high-resolution magnified images *in situ* according to a defined protocol. At the outset, I acquired a basic version of the workroom equipment used by some textile analysts and conservators: a continuous zoom stereomicroscope and c-mount digital camera positioned on an articulating arm affixed to a base post. While this type of arm allows free positioning over a textile, it cannot be moved in precise increments for measurement purposes. For more control over x-y positioning of the textile under the camera, I fastened one centimetre ruled graph paper to the work surface as a guide to move mounted textiles. For macro scale images, I positioned a digital camera on a second stereomicroscope articulating arm. A photograph of my initial equipment setup appears in appendix 6.6.

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[88] Savazzi 2011, 223-296.

While adequate for methodology development, I found that my initial population of images was insufficient for a research methodology based on computer vision. Equipment-based image problems included inconsistent focus in the field of view, poor resolution, and insufficient magnification. Repeated interaction with the microscope for fine focusing caused vibration producing blurred images. Light source reflection resulted in a loss of information and creation of false light artefacts. Manually repositioning the textile mount proved to be time-consuming and unreliable. The weight and size of the equipment made it unsatisfactory for *in situ* application. To meet the technical and portability requirements of my application, I concluded that I would need to redefine my equipment setup.

For assistance in selecting equipment appropriate to my application needs, I met with the staff of the McCrone Institute where I was advised to investigate research grade digital microscope systems.[89] These integrate a computer, display, camera, optics, light source, and software into an independent, portable system. Digital microscope systems have some important advantages as compared with conventional light microscopes including a high degree of flexibility for *in situ* application; their major disadvantage is high cost.

With the assistance of the staff at Hirox USA, I configured an imaging system with many of the features of an integrated research digital microscope at a much lower price. The system comprises a Hirox zoom lenses covering a range of 50-400x magnification with a detachable fibre optic cable and conservation-safe metal halide light source. The lens is paired with a research grade c-mount digital microscope Lumenera camera. The camera includes proprietary image capture software and is connected to a dedicated notebook computer.

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[89] The McCrone Research Institute, located in Chicago, IL is a not-for-profit corporation dedicated to teaching and research in applied microscopy. See the acknowledgements section for the names of individuals helpful to this project.

For the microscope lens, testing is necessary to determine the appropriate magnification for each defined set of data characteristics. To determine pixel size for accurate measurement, the image capture system was calibrated with a stage micrometer. The lens was mechanically adjusted for parfocality in terms of the camera sensor. The aperture ring on the lens barrel adjusts the amount of light passing through into the focal plane.[90] The aperture setting determines the trade-off between image resolution and depth of field and is application dependent. For the textiles included in this study, closing the aperture by one third increased in-focus depth without resolution loss due to diffraction.[91]

Old School Industries, a specialty maker of microscopy fixtures, manufactured a vibration-dampening, portable x-y stand to hold the micro and macro scale lenses. The design for this system was based on my specifications and joint testing and development. The two arms of the microscope carriage each have a separate screw and scale, allowing for precise x-y positioning of the microscope camera lens over the textile as required for image sampling at measured intervals. The focusing block for vertical positioning of the lens includes gross and fine focusing knobs. The vertical post also supports a macro scale camera mounted to an articulating arm. The mounting fixture allows the camera to be positioned on a plane parallel to the textile surface with the aid of a bubble balance. An annotated photograph showing various features of the formal equipment setup is included in appendix 6.7.

c. Resources: image capture

Image capture refers to the set of activities required to achieve a scientifically reliable digital representation of an artefact.[92] Representations should accurately reproduce the

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[90] Savazzi 2011, 78.
[91] Savazzi 2011, 95.
[92] Mudge, Schroer, et al. 2010, Section 2.1.2.

characteristics being measured to ensure data quality and reliability.[93] For the purpose of this project, the objective was to optimise image quality from a computer vision standpoint rather than human perception. This application required a formalised approach to ensure that the system functioned as planned, including equipment assembly, calibration, illumination, and camera settings. In addition, the protocol developed for this project defined standards and workflow practices for image scale, sampling methodology, camera positioning, and data recording (appendix 6.8).

At the outset, my intention was to record the entire textile face in a series of overlapping photographs stitched into a composite image.[94] However, such images are not valid for scientific measurement purposes without integrated equipment for precise positioning.[95] Stitching algorithms rely on alignment and interpolation processes that can introduce errors into the composite image.[96] In addition, the large number of microscopic images required for comprehensive recording of the entire textile face proved impractical for all but the smallest fragments.

Given my focus on weave analysis and error detection, the image capture methodology applied here is based on sampling techniques. The images included in this application are captured as a data series according to defined standards including resolution and exposure time. Selectable settings for the lens aperture, light intensity, and camera software were determined through a series of experiments.

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[93] Wolf, Samarasekera, et al. 2007.
[94] Stitching refers to a combination of multiple shots of adjacent portions of a subject into a single composite image. See Szelinski 2011.
[95] Russ 2007, 258, 260.
[96] Russ 2007, 261.

The diagram presented in appendix 6.9 demonstrates the sampling methodology employed. The textile was positioned under the microscope lens so that the warps were oriented in a vertical direction with the wefts running horizontally. To the extent possible, warps and wefts were aligned with the edges of the image frame.

According to the defined image capture protocol, an initial micro scale image was taken at the lower left edge of the textile showing both warp and weft ends. Using the x-y screws on the carriage arms, the microscope lens was advanced one centimetre in both dimensions, an image recorded, and the process repeated. The resulting series of images taken in a diagonal path across the face of the textile provides comprehensive information about warp and weft characteristics at measured intervals. As an aid in subsequent image processing and to document the specific location of image series for orientation and reference purposes, the starting and finishing times were recorded on a reference diagram.

d. Resources: software development

My initial plan was to obtain measurement data using one of the many commercial or open source image analysis software packages now available. After testing several applications, I concluded that my research programme would require a customised set of tools. Most computer vision packages include tools to develop customised applications based on mathematical algorithms, but require specialised computer programming knowledge.[97]

For advice and assistance, I contacted David Pycock, in the school of Computer Engineering at the University of Birmingham. One of Pycock's students, Chang Su, accepted my project for his post-graduate research project in computer vision.[98] Joint work on the

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[97] In computer vision, an algorithm is a software-based procedure for performing a defined task in a finite number of steps within a processing application.
[98] Su 2010.

project took place over a three-month period in 2010. We focused mainly on developing a methodology for automated detection of binding points. The idea was that binding points would provide an orienting framework for analysis. During this interval, Chang accomplished foundation work, but the scale of the project exceeded the time available.

Nilesh Patel in the school of Engineering and Computer Science at Oakland University accepted the project as a client research opportunity for his students. Joint work on a part-time basis commenced in June 2011 and concluded in December 2012. The results of this research were presented at the 2013 International Conference on Machine Learning and Applications (ICMLA 13).[99] Based on development needs and work schedules, three engineers, Jie Ouyang, Andrey Semenov, and Michael Flynn contributed to the project. To make efficient use of available resources, the team divided the work into two parts: algorithm development and creation of a user interface with an integrated database. Details associated with the application development are included in appendix 6.10.

e. Data collection

Having completed all application development and testing, I proceeded with the data collection phase of the project. To ensure statistically valid results, my original plan was to document approximately one hundred weft-faced compound weave silks in various collections. The advantage of studying a large population of materials is that technical differences among superficially similar textiles are easier to discern. My objective was to find measurable characteristics common to weft-faced compound silks indicating patterns of work practices and demonstrated processes and decisions.

[99] Patel, Gallikar [sic], et al. 2013.

From a practical standpoint, selected textiles had to be located in institutions that were reasonably easy to reach and for which visitor access could be arranged within six months of the date of request. Initially, I tried to assemble a target study group of pieces based on published information in order to ensure a balanced population of materials in geographic and temporal terms. I soon realised that the level of documentation for most institutions is insufficient to support my targeted approach. In addition, some published pieces were unavailable for study for reasons including conservation treatment, loan, or exhibition. A more pragmatic and ultimately fruitful strategy was to request permission to study all silks attributed to Near East or Mediterranean workshops provisionally dated before 1400.

While museum curators and conservators generally support research visits by interested scholars, they must balance access with their responsibility to protect fragile and irreplaceable silks for future generations. Even for the non-interventional research programme defined above, conservators were still concerned about potential deleterious effects associated with my light source, namely emitted heat, ultraviolet exposure and light intensity.

During my data collection phase, I was able to demonstrate the conservation-safe status of my research protocol at several museums. Even so, most institutions are understandably reluctant to take risks on new methodologies. In practice, researchers seeking access to the most precious artefacts, such as the imperial silks, must be established scholars who have published their research in recognised journals in the field.[100] In the future, I intend to pursue access to the inscribed imperial lion silks discussed above.[101] Reportedly, the imperial

[100] For the imperial silks, see pages 7-8, 66, and 69-70.
[101] For the imperial lion silks, see pages 7-8.

elephant silk in Aachen has been withdrawn from view and is no longer accessible for research purposes.[102]

During 2012 and 2013, I documented 125 textiles in ten collections including: Boston Museum of Fine Arts, British Museum, Cleveland Museum of Art, Cooper Hewitt Museum, Detroit Institute of Art, Dumbarton Oaks, Katoen Natie, Kelsey Archaeology Museum, Textile Museum of American, and Yale University Art Gallery. To document each textile according to my research protocol, I took a total of 10,635 photographic images. Analysis of the study group comprising these textiles is presented in the following chapter.

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[102] Verhecken-Lammens and De Jonghe 1995-1996.

PART II: CHAPTER 7 - TEXTILE TECHNICAL ANALYSIS

Complex figured silks are important as both historical and technological artefacts. The purpose of this chapter is to interpret textile remains in a way that is directly comparable with evidence from the textile mention corpus presented in chapter 4. To provide a consistent framework for analysis, textile data are examined in terms of material inputs, textile characteristics, pattern design, and discernable end-use. The goal is to move away from selective interpretation of 'Byzantine' silks toward broader and more objective analysis of surviving material.

As a body of evidence, the characteristics of textile remains differ greatly from textual sources. Major challenges are the lack of secure production location, date, and find spot. The research strategy for this project is designed to establish relative context by comparing characteristics within a large body of similar material. The imaging and analysis methodology described in chapter 6 provides a means to define and capture measurable attributes.

In approaching textiles for technical analysis, two cautions are in order. First, textile researchers tend to interpret textile production problems in terms of approaches used by modern handloom weavers.[1] While first hand knowledge of weaving methods is helpful to the study of textile artefacts, this does means that current conventions and methods can be retroactively applied. Second, the appearance of technical weaving innovations does not mean that former practices ceased to exist. Consequently, the incidence or absence of a particular technical feature does not represent a secure basis for dating.

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[1] Ciszuk 2000, 266.

7.1 Population Characteristics

Before turning to discussion of the process stages defined for this analysis, it is helpful to consider the overall characteristics of the textile fragment study group as a consolidated body. Most museum collections have not been studied to determine weave structure, particularly for damaged or unimpressive pieces. Among the 125 fragments in the study group, the weft-faced compound structure was clearly the dominant technique for producing figured designs with a total of 100 examples. Some of the other twenty-five silks in the study group were woven with structures that developed from weft-faced compound weaves, such as lampas and double weave. Appendix 7.1 provides an illustrated view of the 125 textiles in the study group. Appendix 7.2 contains all analysis for the weft-faced compound weave figured silks attributed to Mediterranean and Near East workshops.

Among the textiles in the study group, 110 comprise only silk yarns. While constructed with a silk weft, two pieces include other fibres in the weft. KTN 650 14 contains a cotton ground weft, although the pattern weft is silk. KTN 156 has a silk warp and wool wefts. Nine pieces include gold in some form, either integrated in the weave or applied to the cloth surface as gilding. Within the study group, 117 textiles are assigned to Near East or Mediterranean workshops between AD 600-1300 with eighty-four silk samites and three silk taquetés.[2] Twelve fragments, six of which are samites and one taqueté, are attributed to East or Central Asia during the same interval.

Two weft-faced compound weave silks are inscribed in Greek as shown in appendix 7.3. On BM AN34973001 the name 'Zachariou' appears over the head of the 'noble rider' figure on the right side of the band. The pattern is tied-up in point repeat so that 'Zachariou' appears in mirror symmetry on the left in reverse letter order. The pattern and structure of DO 165 BZ

[2] For a definition of samite and taqueté see chapter 6.1 and appendix 6.1.

1956 2 is similar, but not identical to the ‘Zachariou’ piece. The silk is inscribed with the abbreviated name ‘Joseph’. Although the inscription only survives on one half of the silk, it was apparently reversed on the other side of the band. Five silks in the collection have inscriptions in kufic script: three lampas and one each samite and double weave.[3]

Three silks in the collection are known to be modern fakes.[4] These were among the ‘Buyid’ silks purchased by museums and collectors during the 1930s and 1940s from dealers Pope and Ackerman.[5] Questionable attributes include unusual representations and colour combinations, and damage inconsistent with an archaeological context.[6] One feature that is evident through objective measurement is the use of reed. In loom technology, a reed is used to space warps in even intervals at the fell line where they intersect with wefts. This technical innovation occurred later than any of the textiles included in the study group.[7] All of the known fakes in the collection display the even spacing of warps that occurs when threaded through dents in a reed. All data pertaining to fakes are excluded from this analysis.

Based on maximum width and height measurements, the total area of all textiles in the study group is about 780 square metres. The survival condition of the textiles in the study collection varies enormously. BM 1907 7-17 1 is the smallest individual fragment in the group and measures 5.5 by 5.0 cm.[8] The largest intact piece is TMA 3 204 with dimensions 66.1 by 100.0 cm. If binding points and other technical features could not be measured reliably due to deterioration or deformation, a textile was excluded. Even so, several

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[3] Samite: CHMNYC 1902 1 244; lampas: CHMNYC 1902 1 220, DO 2009 178 BZ1937 25, DO 177 BZ1929 101; double weave: DO 174 BZ 1926 1.

[4] DIA 36.22; DO 172 BZ1936 50; Yale 1937 4618Z.

[5] See Desrosiers 2004, 456-457; Blair, Bloom, et al. 1992.

[6] Blair, Bloom, et al. 1992, 3-5.

[7] Wild 1988, 37-38. For loom developments, see Wild 1970, 75-78; Broudy 1979, 142; Becker 1987, 270.

[8] All dimension measurements presented in this study show the width value first, followed by height.

fragments such as BM OA756 and CMA 1975 45 are so brittle that they cannot be handled without risk of crumbling. A few silks such as DO 167 BZ 1946 15 and CMA 1974 102 are relatively undamaged with only minor losses when viewed at a macro scale. The fragility of the textiles is apparent under the microscope with fibre breaks visible on all pieces. Based on relative loss and damage, I judged 6% of textiles to be in excellent condition, 36% as good, 42% as fair and the remaining 16% as poor.

In addition to survival environment, post-recovery handling and conservation treatments have had a significant effect on many pieces. Many silks have embedded matter including body fluids and grit from the burial environment. For textiles that passed through the hands of private collectors, cleaning, storage, and display undoubtedly had a major impact on present condition, but were unrecorded by owners. A few pieces such as Yale 1939 635 appear to have been scrubbed, then ironed flat. DIA 47 75 is relatively intact, but remains glued to a cardboard backing. A watercolour tinted to match the ground yarn colour was applied to the cardboard to fill in areas of loss, staining the silk in some places. Early museum treatments could also be damaging and records of interventions were rarely kept. In some cases, cracks and breaks in the textiles were mended together with sewing thread. Fragments of BMFA 07 640b were glued together with a milky adhesive.

Textile mounts vary widely, even within the same institution, and reflect changing standards for presentation and study. The current best practice is to float a fragment in a conservation-safe mount. While always preferable for piece-specific study, access to the reverse side of the silk would have been possible for only about 40% of the collection due to mounting treatments, or because the fragments are attached to other cloths.

Problematic mounts are those that sandwich a textile between glass sheets or press against a cloth surface. Over time, crystalline deposits and residues accumulate on the inner surface of the glass, partially obscuring the textile. A study of deposits on glass in direct contact with mounted textiles found that the residues are fatty acid salts consistent with soap.[9] When washed with hard water, the soap residues leave behind insoluble calcium and magnesium fatty acid salts.[10] While some textiles might have been exposed to cleaning compounds during their useful life, the widespread incidence probably indicates efforts to clean textile finds.[11] Even in conservation-safe open mounts, salt crystals were especially visible in certain collections.

Collections documentation varies widely by institution and reflects the interest and knowledge of former curators, as well as collection focus and publication histories. Most silks from both the British Museum and Katoen Natie have been documented according to CIETA methods. The Cooper Hewitt collection has been extensively studied, but never published. While I was able to study textiles from the collection, documentation was unavailable to me because of a museum renovation project.

7.2 Material Data

Yarn selection and preparation processes are integral to the appearance and performance of finished cloths. Even an expert weaver cannot overcome the effect of inconsistent yarns or poor quality fibres on a finished textile. Despite the recognised importance of components, few studies of historical silks have considered yarns in detail. The main constraint has been lack of a reliable means to measure specific attributes in intact textiles.

The literature of the field includes some research for staple fibres. El-Homossani's 1988 protocol for reconstructing early compound weaving technologies provides important

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9 Heald, Commoner, et al. 1993.
10 Heald, Commoner, et al. 1993, 15.
11 Heald, Commoner, et al. 1993, 16.

methodological and practical information.[12] Cooke and El-Gamal explored methods for measuring and spinning fine yarns.[13] Some researchers have described the benefits of using digital image analysis to measure yarn diameter.[14]

a. Material analysis

This discussion of yarn characteristics opens with a brief summary of observed fibre and texture qualities. Mean values for yarn diameter and twist are derived from a statistically valid number of measurements of intact components across the face of a textile. To provide an accurate representation of textile properties, measurements of visibly degraded or damaged areas were excluded.

The majority of historical silks in the study collection are constructed from filament yarns.[15] Only two textiles include spun silk yarn components. BM 1895 8-10-20-31 is unusual with both binding and main warps of spun silk. Both elements are plied (S2Z) to provide additional strength. As compared to the binding yarn, the main warp has a courser appearance and is less finely spun, possibly for economic reasons. BMFA 25 196 has a Z twist filament binding warp, but the main warp is made from S twist spun yarns, probably as a cheaper alternative to filament silk.

Yarn appearance is determined by a number of factors including the quality of the silkworm rearing and production processes. Discriminating fibre quality by visual inspection is difficult, especially for fragments found in historical contexts. The localised or overall fibre damage observed on some pieces could have occurred at any point during use or in post-

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[12] El-Homossani 1988, 28-29.
[13] Cooke and El-Gamal 1990, 69-74.
[14] Cooke and Peacock 1992, 218-228; Cork, Cooke, et al. 1996, 337-345; Cardomone, Damert, et al. 2002, 906-916.
[15] For silk yarn characteristics, see chapter 6.1.

recovery handling. While objective measures do not yet exist to characterise yarn texture in historical textiles, some features are obvious in high-resolution images.

In general, the silk fragments attributed to Central and East Asia have fibres that are more regular, smoother, and glossier than for all others in the study group. Yarn imperfections such as knots and slubs are rare on Asian silks, but are visible on many silks attributed to Mediterranean and Near East workshops, even those with impressive pattern designs. Both warp and weft yarn elements on TMA 711 9 and BMFA 33 519 are noticeably more 'hairy' than the majority of silks in the collection. Short filament lengths can produce hairy yarns because more cocoons are required to be cast-on to produce the desired weight yarn.[16] The hairy fibre texture gives both silks a distinctively matte appearance because reflective light is broken up by the uneven surface.

For weft-faced compound structures, the warp is the active component in the weave structure and has to withstand the tension and friction associated with repetitive opening and closing of sheds for weft insertion.[17] Measurements are recorded for binding warps, which are visible on the cloth surface. Main warps are covered by weft yarns, so can only be observed at the edges of a textile fragment and in damaged areas.

In studying binding warps, two objective characteristics are twist and yarn diameter. All but two of the weft-faced compound weave silks in the study group have a twisted warp. Much has been written about the reasons for twist direction including conservation of established craft practices, transmission of skills, and cultural contact.[18] For single strand filament yarns, the direction of twist does not influence the mechanical properties of a

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[16] Mauersberger 1954, 688.
[17] For textile structural components, see Lord and Mohamed 1982, 17-19. See chapter 6.1 for combination of yarns into the weft-faced compound weave structure.
[18] For example see Bellinger 1959; Peterson 1993.

finished textile and is considered to be a convention.[19] Among the weft-faced compound weaves in the collection, 95% have a Z-twist binding warp. This high degree of consistency evidently constituted a standard practice that coincided with the use of the weave structure in both the West and in Central Asia.

While important as a parameter for characterisation, twist direction is a binary choice and offers limited information for analysis. Studies of historical textiles seldom refer to the amount of twist applied to a yarn. Exceptions include Bellinger, who noted twist angle in studies of sixteenth-century Turkish and Venetian velvets and brocades;[20] and Eastwood and Walton, who recommended estimated twist measurements for archaeological textile documentation based on protractor readings.[21]

Surface helix angle measures the relationship between the twisted fibres on the surface of the yarn with the longitudinal axis.[22] As a function of both turns per unit length and yarn width, this measurement can be used to compare yarns of different diameters.[23] El-Homossani described measurement of yarn helix angle in his protocol for reconstructing weaving technologies using an electronic image analyser.[24] The most extensive analysis to date was developed in the mid-1990s using digital analysis methods available at the time.[25] The authors classified applied twist into three categories: low (0-15 degrees), medium (15-30 degrees), and high (over 30 degrees).[26]

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[19] See discussion by El-Homossani 1988, 28.
[20] Bellinger 1959; El-Homossani 1988, 28.
[21] Walton and Eastwood 1984, 11.
[22] El-Homossani 1988, 28; Hearle, Grosberg, et al. 1969, 63.
[23] El-Homossani 1988, 28.
[24] El-Homossani 1988, 28.
[25] Cork, Cooke, et al. 1996, 337-345.
[26] Cork, Wild, et al. 1997, 20.

The measurements presented here represent the first instance in which helix angle is documented for comparative analysis of historical silks. At the outset of this study, my expectation was that the angle of twist would vary by production location with differences based on factors such as workshop skill and textile specifications.[27] To derive a valid sample, a number of measurements are necessary to determine the evenness of twist distribution.

Among the weft-faced figured silks attributed to the Near East and Mediterranean, 83% have average helix angles in the range of 10-15 degrees. Values for most remaining textiles are grouped around this mean. Looking at data for each individual textile, the majority of values are around 13 degrees, but some measurements are outliers at about 5 and 32 degrees. The distribution of data suggests that low or high measurements are local effects in the yarn caused either by twist that was not evenly distributed over the full length of the yarn, or that in handling, twist was unintentionally removed or inserted.

The consistent clustering of helix angles around 13 degrees and the near uniform choice of Z twist is remarkable given the wide geographical and temporal range represented by silks in the study collection. A possible explanation is that twist was not an explicit manufacturing specification, but was determined by methods and equipment exclusive to silk that moved with the material as local industries developed. This implies that yarn production methods were material-specific, overriding established craft habits associated with other fibres. For example in Egypt, linen and wool and cotton were generally spun with an S twist and often plied.[28]

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[27] See chapter 6.3 for discussion of material workshop specifications.
[28] De Moor, Verhecken-Lammens, et al. 2008, 65-66.

The methodology developed for this study also represents the first instance in which yarn diameter has been systematically measured for historical silk fragments.[29] Binding warp yarn diameter measurements in micrometres (um) are grouped into five categories: fine (less than 169 um), medium fine (170-209 um), medium (210-239 um), medium coarse (240-279 um) and coarse (greater than 280 um). Measurements follow a normal distribution with the majority of textiles in the middle categories.

Unlike warps, weft yarns are not subject to mechanical stress and provide filling for cloth construction.[30] Comparing the binding warp and ground weft diameters for each silk provides a perspective on the selection of yarn components for silk weaving. The ratio of these measurements shows that 54% of silks in the collection have equal binding warp and ground weft diameter widths, despite having different functional roles and construction techniques. In 31% of silks, the diameter of the binding warp is larger than the ground weft resulting in a prominent binding warp that detracts from the appearance of the represented design. The binding yarn is finer than the ground weft in 15% of the examples, possibly as a later development to minimise the appearance of binding warps on the textile face.

Excluding four instances of special yarns, all weft-faced figured silks in the collection have wefts with no discernible twist. The absence of twist provides a smooth, reflective surface interrupted only by the binding warps used to secure the wefts in place. A second reason for the lack of twist is that yarn fibres spread out between binding points to disguise the warps underneath. Comparing the diameter of ground wefts with measurements for

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[29] Theoretically, recording yarn diameter introduces measurement variation by the fact that images are two-dimensional representations of cylindrical-shaped yarns. However, consistent lighting and focus mitigated this concern with clearly delineated yarn edges throughout the image series.

[30] Lord and Mohamed 1982, 17-19.

dominant colour pattern wefts shows a high degree of consistency in selection of weft yarns for all silks in the collection.

An enigmatic finding from this study coincides with observations by Desrosiers and Verhecken-Lammens regarding the large diameter differences in alternate wefts on some textiles.[31] Alternate weft diameter differences are clearly visible on at least ten textiles in the study group including TMA 11 16 and CHMNYC 1902 1 248. Analysts have generally considered discrepancies in weft diameters as faults attributed to inconsistent materials.[32] Use of alternate weft diameters may have been intentional as a means of reducing the appearance of diagonal twill lines on the face of a textile or as a marker to keep track of work. Whatever the cause or purpose, the practice indicates that two shuttles were used to weave each weft colour.

Only one samite in the collection includes gold foil-wrapped yarn. CMA 1950 2 is a partial pattern unit of a large roundel containing a double-headed eagle woven in 1/3 samite.[33] The ground weft colour was once red, but has now faded to pink. The disadvantage of using a foil-wrapped yarn in a samite structure is that weft yarn fibres cannot spread out to cover the warps, which are partially visible on the textile face. To make the exposed yarns less noticeable, both warps were dyed red to match the ground colour as shown in the photo in appendix 7.4. While the silk was probably impressive during its useful life, the structure itself is poorly suited to wrapped yarns. Two other silks in the collection include wrapped weft yarns constructed from a gold gilded material with the same disadvantage as gold foil.[34]

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[31] Desrosiers 2004, 16-17, esp. ill. 4; De Moor, Schrenk, et al. 2006, 92-94; Verhecken-Lammens 2000, 42, fig. 5.
[32] See Desrosiers 2004, 16.
[33] Pattern wefts were formed by gold foil strips wrapped in a Z direction around a Z twist golden yellow dyed silk core.
[34] CHMNYC 1902 1 240; CHMNYC 1902 1 978.

These fragments may explain why there are few surviving examples of metal yarns in figured silks until the development of true lampas.

b. Material summary

This discussion of material characteristics demonstrates how the additional information obtained from the computer vision protocol developed for this project aids in documentation of specific processes and component attributes. Some silk yarn textural properties are observable in high-resolution images, especially the incidence of hairy silk. Measurement of surface helix combined with observed direction contributes objective evidence to definition of groups based on a common set of technical features. The nearly uniform choice of Z twist direction combined with the surprisingly high consistency of warp twist measurements among textiles with a wide variety of attributed dates and production locations is a significant finding that suggests yarn preparation methods and equipment methods were adopted coincidentally and were exclusive to silk. A combination of technique and equipment may explain one aspect of the intra-regional transmission of silk textile production practices.

Objective measurement of yarn diameter provides information pertaining to the selection of components and their relative relationship to each other. Comparison of components provides some process information such as the use of two shuttles for each weft colour. Measurements also provide a means of specific comparison of superficially similar textiles. The use of metal yarns, either as foil or in the form of gilded paper, demonstrates the structural limitations of wrapped yarns for application to weft-faced compound weaves.

7.3 Textile Data

a. Textile analysis

The textiles included in the study collection show a number of decisions pertaining to the way that yarns were combined. Among the silks attributed to the Eastern Mediterranean and Near East, eighty-five are samites and three taquetés.[35] With one exception, all samites have a 1/2 binding ratio. This ratio indicates that a weft is bound by one warp, and then floats over two warps. Only CMA 1950 2 has a 1/3 binding ratio.

Although use of a tabby binding structure for weft-faced compound weaves was probably devised before twill, incidence does not provide a basis for dating historical silks.[36] Choice of weave structure involved a number of factors including material properties, desired appearance, and intended use. Two of the taquetés in the study group are refined compositions attributed to Islamic workshops in the later centuries of the study period.[37]

During weaving, binding warps are lifted in a sequence that is repeated throughout the textile length unless a weaver makes a mistake. In samites the network of binding points appear as subtle diagonal lines across the textile face. Lines that are oriented to the right have a Z twill direction; S twills have diagonals to the left.[38] Twill direction is considered to be a workshop convention and does not alter textile appearance or function.[39] Among the Mediterranean and Near East silk samites, thirty-four are Z and forty-nine are S twills. At least three silks show both S and Z twill directions indicating loom preparation errors.[40]

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[35] See chapter 6.1 for an explanation of these structures.
[36] See CIETA 1987, 26.
[37] CHMNYC 1902 1 978; CMA 1975 45. For dating see Weibel 1952, pl. 85; Otavsky 1995, 135.
[38] For diagrams and description of twill direction, see Burnham 1980, 154-159.
[39] Desrosiers 2004, 16-17.
[40] BMFA 47 1459; DO 166 BZ 1953 2 126; TMA 11 16.

Another structural parameter is the ratio of binding to main warps. Sixty of the silks in the collection have a 1:1 binding to main warp proportion; twenty-three have a 1:2 ratio. CHMNYC 1902 1 211 has a ratio of 1:3 binding to main warps. While all silks demonstrate choice of a specific ratio, many include mistakes in which extra warps are included. The frequent occurrence of this error in about 8% of the silks visibly detracts from the appearance of the cloth.

The use of multiple main warps increases the length of pattern floats as a means of enlarging the horizontal pattern area. While textile researchers generally agree that the practice was a technical innovation, both the extent and date of this development is unknown.[41] Muthesius relied on multiple warps as a basis for dating the silks included in her studies.[42] The implicit assumption is that all producers adopted the technique during the same interval, which is possible, but unlikely. Moreover, the relevance of this characteristic for dating purposes has not been verified by radiocarbon dating studies.[43]

Turning to consideration of structural attributes pertaining to wefts, the number of yarns included in a single pass generally coincides with the number of weft colours incorporated in the design. Among the Mediterranean and Near East weft-faced compound weave silks in the study group, fifty-three are bi-colour silks with each pass comprising two wefts of different colours. Among the thirty-four polychrome silks, twenty-three use wefts in all visible colours on a continuous basis throughout the entire textile. The remaining eleven silks use additional colours in discontinuous bands. In some fragments, the introduction of an interrupted colour weft is obvious. On CHMNYC 1902 1 248 bands of blue silk are visible beneath the lighter coloured wefts. On several other pieces, a colour weft is continuous throughout the textile, but

[41] Desrosiers 2004, 14, 16; Wilckens 1991, 28; Muthesius 1997, 145-146.
[42] Muthesius 1997, 34-57.
[43] For radiocarbon dating related to weave structure, see Verhecken-Lammens 2007, 195.

the colour of the yarn changes according to the design. For example, on TMA 711 9 3a, a dark green weft was substituted for a tan coloured yarn in horizontal bands.

The incentive to design and execute silks with interrupted weft colours was evidently economic. Superficially this technique gave the impression of a more expensive polychrome silk. Less silk and labour were required by forgoing insertion of an unseen pattern weft. Alternatively, continuous use of polychrome wefts throughout a textile created a heavier, more evenly weighted silk with all weft colours available throughout a length for design purposes. An important qualification is that some sophisticated silks attributed to Islamic workshops combined multiple pattern units in a series of bands resulting in complex compositions. Two noteworthy examples in the collection are CHMNYC 1902 1 978 and TMA 3 204.

The order in which colour wefts were introduced into a cloth as it was being woven relative to pattern direction provides another example of craft habit.[44] Among Mediterranean and Near East weft-faced compound weaves in the collection, 70% show that the ground was the last weft inserted in a pass. While the order in which particular colours were inserted did not alter the amount of work required, the use of a returning weft shuttling order represented a significant reduction in labour and time. Rather than changing the pattern harness for each weft pass as required in an alternating 1, 2, 1, 2 sequence, the same shed remained open for yarns to be inserted in a 1, 1, 2, 2 repeating order.[45]

The work savings benefit of weaving with a reversing weft has been noted by a number of researchers,[46] but most collections have not been analysed for this attribute. Within the

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[44] For technical analysis involving this attribute, see Verhecken-Lammens 2007.
[45] Desrosiers 2004, 16.
[46] For example, see Desrosiers 2004, 16.

study group, 60% of samites were woven with the reversing shuttle insertion method. Wefts in the remaining fragments were inserted in an alternating sequence. In a few textiles such as KTN 855a, both sequences were used in the same textile, depending upon the number of colour wefts in a pass. In bi-colour weaves, the difference between the two insertion methods is barely perceivable. However, with three or more colours used coincidentally, the effect of the returning weft in areas of multiple colour changes resulted in bare warps due to a 'stacking' effect if wefts were not densely beaten-in. Bare warps are particularly visible on some large pattern unit polychrome silks such as the elephant (CHMNYC 1902 1 211) and griffin (CHMNYC 1902 1 214) fragments as shown in appendix 7.5.

In textile analyses, one of the most commonly published indices for comparison is weave density in terms of warp and weft yarns.[47] To provide a consistent basis for comparison, all measurements are presented in terms of average warp groups and average weft passes per cm. Together these measurements provide an indication of weave density. Relevance for characterisation is limited by lack of a reliable means to measure the space between yarns. In the future, the imaging methods developed for this project could be refined to devise a means to estimate yarn linear density.[48]

Warp group density is determined by textile specifications and design characteristics. It was fixed when a loom was prepared, but variations often occurred as weaving progressed. Weft density is determined by the intended pattern design and also indicates weaving quality. If wefts are packed too densely, the intended design is compressed in a vertical direction. The opposite effect occurs if wefts are not consistently beaten-in. Maintaining consistent weft

[47] For example, see Burnham 1980; Emery 1980. See chapter 6.3b for density specifications.
[48] See the protocol developed by El-Homossani 1988, 27-30. A strictly objective measurement process would require destructive testing which is unacceptable for historic textiles.

density was obviously difficult. Nearly all fragments with more than one surviving vertical pattern repeat show some variation in height.[49]

A relative measure of textile density is provided by the ratio of warp to weft groups per cm. About 70% of the fragments in the collection fall within a range of 0.4 to 0.6, which suggests that a 0.5 ratio was a common design standard. The silks that fall outside of this range each have structural attributes that make them different from the majority of weaves. Fragments from two different silks in the British Museum collection, BM 1895 8-10 33 and BM 1895 8-10 15 7, share the common characteristic of relatively low warp density.

At the outset of this project, my intention was to define, categorise, and measure the incidence of weaving errors on a comparable basis among textiles in the study group.[50] The process of preparing and executing complex weave figured textiles was prone to errors and all pieces contain some faults. Some lower quality weaves display many different types of errors within a small area. Hence, a comprehensive examination of the incidence of faults observed on the fragments in the study collection would exceed the scope of this work. Although errors are noted by some researchers in studies of a single or small group of fragments, no consolidated guide has been written to date. Consequently, recognition of specific faults and their significance is confined to a small group of specialist researchers. An illustrated reference that standardises error assessment methods in a coherent framework would represent a valuable contribution to the field. To convey the value of error analysis in discriminating among superficially similar textiles in the study group, three types of errors are discussed below.

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[49] For the occurrence of this problem on the ‘imperial elephant’ silk, see Vial 1964.
[50] See chapter 6.3d for discussion of error characteristics.

The first error stems from equipment that was unsuitable for the weave structure. Several of the samites in the study group share a common problem related to the lack of a separate beam or other tensioning device for the main warp. In compound weave structures the binding warp moves over and under all inserted wefts; less 'take-up' is required for the main warp because it travels less total distance.[51] As a result, the loose main warp meanders under the wefts and sometimes appears as a loop on the cloth surface as on CMA 1947 192 and DO 168 BZ 1939 32. An image showing this error is included in appendix 7.6. Some researchers have discussed use of separate warp tensioning devices as a separate technical development.[52]

Another type of error pertains to the coordination of work between a weaver and assistant.[53] This coordination error appears on some textiles woven with a returning method of weft insertion.[54] To avoid the appearance of main warps on the cloth surface, the change of pattern and binding sheds must be coordinated in the following sequence: 1*,2/2,1/1*,2/2,1.[55] The binding shed must be opened separately from a change in the pattern shed between returning wefts of the same colour. On some silks, the weavers got out of step, so that the change in pattern and binding sheds coincided in a 1*/1,2/2 sequence. The photos included in appendix 7.7 show this error. Among silks with returning weft sequences in the study group, the coordination error is visible on more than 50% of fragments.

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[51] See CIETA 2006, 37.
[52] For example, see Granger-Taylor 2000, 41.
[53] See chapter 6.1 for the impact of the drawloom on organization of work.
[54] The most complete explanation is provided by Verhecken-Lammens 2007.
[55] Verhecken-Lammens 2007, 200-203. According to the notation used by Verhecken-Lammens a '*' symbol designates a change of the pattern shed. The '/' is the conventional symbol to indicate a change in the binding shed. The numbers indicate 2 different colours in the simplest version of this weave structure.

A third type of error stems from the tendency of selvedges to draw-in and subtract from the width of the cloth as weaving progresses. Draw-in was especially problematic for weft-faced compound silks woven in wide widths. In order to reproduce pattern designs consistently across the face of a textile, weavers needed to maintain consistent warp spacing throughout an entire length. On KTN 1757 a selvedge survives with a series of small holes in the edges. This indicates that a warp spreader was used as an aid to maintain a constant width. BMFA 96 354ab provides a striking example of warp spacing problems. This silk is notable as an inferior reproduction of confronted mounted riders in a roundel medallion. The effect of uneven warp spacing is clearly evident in the comparison as shown in appendix 7.8.

b. Textile summary

Summarising this discussion of structural characteristics, the similarities and differences among weft-faced figured silks in the study collection provides a perspective on the application of weaving technologies in the region and suggests developments over time. Yarn components can be combined in a wide variety of different ways to produce pattern effects in one form or another. The dominance of 1/2 samites in the collection demonstrates widespread adoption of the structure as a means of patterning silks. This long-lived innovation provided a smooth cloth surface to projected the qualities of silk.

As this analysis has shown, craft habit explains some of the decisions demonstrated in surviving fragments. Twill direction and colour weft insertion order are examples of two parameters that were probably common to all silks produced in an individual workshop. The incidence of binding tie-up mistakes is probably higher than is generally realised and indicates the need to consider twill direction among a group of characteristics used to assign workshop groupings.

Some other choices reflect a long-term trend toward more efficient production. The use of multiple main warps increased the patterning area for the same amount of work. It also reduced the visibility of the binding warp without significantly changing the structural integrity of the cloth. The widespread adoption of the reversing method of weft insertion decreased the effort involved in manufacturing complex silks without visibly detracting from the quality of the cloth, unless a number of colours were used. Other measures such as use of interrupted colour wefts reflect a producer's decision to weave a lesser quality of polychrome silks by economising on materials and labour.

While the relevance of density alone as a characterisation parameter is limited, the consistent ratio of warp to weft density indicates a rule of thumb that appears to have been conventionally applied by many workshops. Careful error analysis provides significant information about various cloths that share structural commonalities, yet are very different in appearance. Problems stemming from equipment limitations, the difficulty of coordinating work, and compressed designs due to draw-in provide process information that is unavailable through other means.

7.4 Pattern Data

a. Pattern analysis

Technical design characteristics have a large bearing on the appearance of figured silks.[56] Pattern evaluated from a technical point of view provides a number of parameters to discriminate between silks with similar designs. Objective characteristics include symmetry, information content, colour, scale, and resolution. Comparison of features among a population

[56] For mechanical reproduction of patterns with a drawloom, see chapter 6.1. For pattern characteristics, see chapter 6.3.

of fragments provides a basis to discern common patterns of practice as well as variations and technical developments.

In figured weaves the pattern unit is the basis for mechanical reproduction that can be extended horizontally or vertically through use of symmetry. Within the study group, only five Mediterranean and Near East samites appear to have been woven with a straight repeat.[57] Eighty-two silks employed some element of mirrored symmetry in their design.[58] Forty silks survive in a form that shows pattern orientation in a warp direction for more than one unit. Among these, only eleven pieces demonstrate mirror symmetry. Three of these silks, BMFA 31 129, DO 165 BZ 1956 2, Yale 1947 201i, have representational designs that reverse direction in alternate pattern rows. From the available evidence, the majority of silks in the collection appear to have been woven as one-way designs in a vertical direction.

Another design characteristic is pattern orientation relative to the warp direction. The large majority of Mediterranean and Near East silk samites were woven with the pattern perpendicular to the warp; only four pieces were oriented in a parallel direction. Among these, BM OA756 and BMFA 48 379 were woven with a straight repeat in the weft with mirrored symmetry in the warp direction. By extension to wool taquetés with the same pattern orientation, these silks are considered to have been woven early in the study period.[59]

Considering information content, silks can be separated into representational and non-representational groups. Excluding three fragments too small to analyse, seventy-five Mediterranean and Near East weft-faced compound weaves have representational designs including vegetal, animal, or human motifs, alone or in combination. Among the thirty-four

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[57] For a description of straight and point repeat design, see chapter 6.1.
[58] BM OA756; BMFA 11 90; BMFA 48 379; CMA 1950 520; TMA 11 30.
[59] For wool tacquetés, see .Verhecken-Lammens 2007. For pattern orientation, see King 1981.

animals represented on silks, birds are the most common and appear in thirteen fragments. Among these, a double-headed eagle or peacock appear on three pieces. Other animals include five griffins, three antelopes, three lions or leopards, two elephants, a rabbit, a senmurv, and others.

The most common vegetal motif is the candelabra tree, which appears on fourteen fragments. The two silks woven with a pinecone motif may be a variation on the same form. Two other silks have a strong classical theme. BMFA 11 90 shows a shepherd surrounded by animals, and TMA 711 9 is known as a '*Dioscures*' silk. Other human representations are seven 'Amazons', six 'crowned saints', four 'noble riders', two 'Samson' fragments, and a hunter figure.

In addition to the central figures, frames were integral to most representational compositions.[60] They provided a boundary to focus interest and a means of integrating pattern units. Among the eighty fragments large enough to determine if a frame was included in the design, 80% use some sort of boundary device. The roundel is the most common frame and appears on 50% of the representational silks with frames. A band or rectangle was used on 10% of silks, apparently as a line to cut apart for tunic decorations. Structures based on diagonal lattices comprise 15% of the collection. The diagonal line of the composition provided a means of overcoming the rigidity that typifies many figured silks, and may have anticipated more complex design developments.

Pattern drafting also involved colour choices. Interpreting the meaning associated with the colours visible today is problematic for archaeological textiles. In some cases, exposure to

[60] For a discussion of the use of framing devices in textile pattern designs and the incidence of 'ready made' medallion forms, see Bellinger 1961, 4.

substances and chemical reactions within a closed environment dramatically altered hue.[61] Several of the textiles in the collection that now appear to be green, such as BMFA 07 640a, were probably blue during their useful life. Dyes on several textiles have now faded, which alters the intended visual effect.

Despite these limitations, two colour-related design features are evident in the weft-faced silks in the collection. The first involves the use of a dark colour for the ground and a light colour for pattern wefts. Among the silks with representational designs, only one fragment, BMFA 33 648, has a light colour field with a darker colour pattern design. Fragments BMFA 01 8342 and BMFA 25 159 had what was probably a red ground with a pattern design in black. One reason for the choice of a dark ground and a light pattern colour was the weave structure itself. A darker colour pattern weft is partially visible behind a light ground, creating a blended colour. Use of a dark colour ground and a light colour pattern maximised optical contrast, making designs more readable.

The visibility of binding warps on the face was reduced in one of two ways. Among the seventy-five representational patterned silks in the collection, warps were obviously dyed to match the ground weft on twenty pieces. On each, the warp colour is significantly more faded than the weft, suggesting that cheaper and more fugitive dyestuffs were used. The fact that some warp dyes may have faded entirely suggests that reliance on coloured warps as a basis for attribution is unreliable.[62] Most of the remaining silks have brown warps. While the brown warp colour is different from the ground weft hue on all representational pieces, the majority are matched in terms of colour value. Most silks with dark blue or purple wefts have warps dyed a dark or medium brown colour; fragments with a red ground weft have warps in

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[61] See Hofenk-de Graaff and Roelofs 2006; for current methods in dye analysis, see chapter 5.7.
[62] Falke 1913, I, 48; King 1966; Martiniani-Reber 1986, 14-15; Desrosiers 2004, 20.

medium brown or tan. While binding warp colour is commonly noted in technical analyses and catalogues discussed above, the predominance of warps matched to ground wefts by colour value has not been noted in the literature.

In addition to mechanical patterning constraints, the drafted design for weaving had to conform to available loom equipment. Considerations included the size of the pattern repeat, loom width, and pattern harness capacity.[63] The width of the finished textile had to accommodate the planned number of pattern repeats in a horizontal direction. The number of warp ends that could be independently controlled determined pattern capacity.[64]

The fragmentary state of many of the silks in the collection limits the extent to which pattern units can be studied in terms of physical dimensions. Nevertheless, it is possible to compare fragments on a relative basis to gauge the complexity of loom tie-up. The widest pattern unit in the collection is CHMNYC 1902 1 221 with a total pattern width and height greater than 42.7 cm. The silk has about 14 binding warps/cm and 26 weft passes/cm. The next largest width is CMA 1950 2 with a pattern unit size of 26.8 by 48.6 cm. The silk was woven with point repeat making the complete visual unit more than 50 cm wide. This silk was also more densely woven with 32 binding warps and 32 passes per cm. These data provide a basis for comparison with the inscribed silks discussed below.

Four of the large pattern unit silks in the collection display a one-way central figure within a symmetrical roundel frame.[65] The large size of the repeat width required a loom suitable for tie-up of nearly twice the number of different pattern rows than if the central figure were enlarged by horizontal mirror symmetry. Departure from a symmetrically

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[63] El-Homossani 1988, 32.
[64] Jain 1994, 53-54.
[65] CHMNYC 1902 1 212; CHMNYC 1902 1 214; CHMNYC 1902 1 221; CHMNYC 1902 1 222.

composed central figure introduced additional complexity into the process and required skilled designers and weavers. Silks with large one-way central figures are among the highest status textiles in the study group based on the specialised equipment and skills necessary for their production.

The smallest representative figured patterns have a width of only 3-4 cm but are 11-13 cm high. This sort of narrow width pattern unit was described by King and is considered to be an early weave type from looms with limited patterning capabilities.[66] The average of all pattern unit dimensions in the group is 9 by 18 cm. The pattern unit size for non-representational silks is smaller with average dimensions of 1 by 2 cm. The limited number of different pattern rows indicates that such pieces could have been woven with shed sticks or a shaft loom, rather than a drawloom.

Once a pattern design and lifting sequence had been defined, the warp could be tied onto the loom. For a repeat in a horizontal axis, the main warps had to be duplicated precisely for each pattern unit across the loom. Vertical repeats of wefts were recorded by the simple or similar device.[67] The process of tying-up a loom was tedious and mistakes were common. For example, a major pattern tie-up fault occurred in the silk attributed to the tomb of Pepin the Short (BMFA 33 648). The roundel containing the griffin figure on the left has many mistakes resulting in significant deformation as shown on appendix 7.9. Another example of a tie-up mistake is provided by DO 169 BZ 1972 10. The diagram presented in appendix 7.10 provides a detailed illustration of a tie-up error on this textile.

The smallest possible pattern element in a woven silk comprises the width of one warp group and the height of one weft pass. The average dimensions of this area provide an

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[66] King 1981, 96-99.
[67] See CIETA 2006, 34; Broudy 1979, 131.

indication of resolution for comparison among silks in the collection. Pattern steps comprise the smallest design units in a composition.[68] Depending upon the diameter of a yarn, warp density, and the patterning capacity of a loom, the majority of silks have warp steps of one or two groups. Given the small diameter of yarns, weft steps rely on multiple passes. Most silks in the collection have a weft step of two or four passes. Depending upon design requirements, some fine details might incorporate steps smaller than those used elsewhere in the silk.

From a weaving standpoint, successful execution of a rounded shape is an indication of the technical capabilities of a workshop. To achieve a balanced and proportionate appearance for curves and to avoid stepping, certain design conventions were applied. A successful curve requires sufficient pattern resolution and gradation to avoid a stepped design.[69] Although badly degraded, CMA 1975 45 is one of the most gracefully drafted silks in the collection. Similarly, CHMNYC 1902 1 244 displays smooth lines and curves with a gradual reduction in pattern step proportions, but is in poor condition.

Stepped outlines are evident on several silks in the collection. Departure from the 1:2 ratio of warp to weft steps resulted in stepped curves. Two examples of stepped pattern designs due to the ratio of warp to weft steps are: BMFA 31 129 with 5 warp to 4 weft steps and CHMNYC 1902 1 211 with pattern steps of 2-3 warps and 2 wefts. With pattern steps of 2 warps and 4 wefts, the design on Kelsey 94151 and TMA 11 23 is out of proportion because of the width of the warp groups relative to the weft.

Textile historians have long noted that certain pattern designs appear to have been reproduced in slightly different forms by workshops.[70] Comparing design elements in figured

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[68] See CIETA 2006, 13.
[69] For the use of a gradation formula for curves and circular shapes, see Grosicki 2004, 229.
[70] Bellinger 1961.

textiles dating from the seventh to tenth centuries, Stauffer concluded that the uniformity of dimensions and other design elements over long intervals suggests the use of cartoons and pattern books to record and reproduce designs as well as to transfer representations to other workshops.[71]

While such illustrations may have contributed to the exchange of certain motifs within the region, the characteristics of related pattern designs suggest that they were reproduced from other cloths. Simple representations provided none of the detailed information required for the involved process of adapting a design for the loom. As discussed in chapter 6.1, preparation of a loom for memorised reproduction required a design to be rendered in terms of a grid that was adapted to the dimensions of warp and weft yarns, intended density, and pattern scale. A tie-up plan for the figure harness that divided the main warp by weft colour for each pattern row was necessary to execute a figured weave. In addition, a lifting plan was required to sequence each pattern row in the required order.[72] A simple drawing alone would have been unsuitable for pattern reproduction by a drawloom workshop.

In contrast, a finished textile provided a production record of some of the steps used to produce a figured cloth. While a pattern harness still needed to be prepared, some of the detailed work associated with preparing a pattern tie-up and lifting plan could be avoided. To differentiate original textile designs from reproductions, Bellinger described patterns woven on looms suitable for their production as ‘primary specimens’.[73] Within the study collection, two patterns provide clear evidence of reproduction from other cloths. A design that appears

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[71] Stauffer 1992, 49. See chapter 5.7 for the use of cartoons as weaving diagrams.
[72] For examples of pattern tie-ups and lifting plans for particular weft-faced compound weave Mediterranean silks, see Vial 1961; Becker 1987, 111-143.
[73] Bellinger 1961, 1, 3.

to have been reproduced in various workshops is the ‘Amazon rider’ silk.[74] Six samite fragments with this design are included in the study collection, all of which have the same structural attributes.[75]

The uneven survival condition of fragments with this motif means that detailed comparison of entire pattern units is not possible. Instead, I focused my analysis on two common features visible in several silks: the horses’ heads and the Amazon riders’ heads. Comparison of specific details shows that the quality of the pattern tie-up varies significantly among the fragments. In comparing the horses’ heads in appendix 7.11, fragment DO 167.BZ.1946.15 shows clear, elegant lines with a skilfully drafted design. By comparison, fragments TMA 11.16 and BMFA 0764a are notably coarser. Comparison of images for the Amazons’ heads shown on appendix 7.12 demonstrates the same characteristics.

This analysis suggests that high quality pieces such as the Dumbarton Oaks silk provided a guide for reproduction. While the particular reasons for imitation are unclear, the skills required to draft an original design and to adapt it to the loom required expertise. Equally, the number of surviving related pieces and the many versions of the design suggest reproduction in response to market demand. While the specific progression of copies used as models for new versions is now lost, surviving fragments indicate that the design became debased as inaccuracies and adaptations to different looms accumulated.

The ‘vine lattice with birds’ pattern is another example of a reproduction series with slight changes in design features as shown in appendix 7.13. Large fragments of this design survive in many collections, but lacking a dramatic central figure, the silk has seldom been analysed or published. In the study group, six ‘vine lattice with birds’ fragments in two

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[74] Stauffer 1992.
[75] BMFA 09 127; BMFA 15 1123; CMA 1983 139; DIA 47 75; TMA 11 21; Yale 1939 635.

different colour schemes are held in five different collections. The motifs were clearly derived from a common source, but each shows slight differences, particularly on central vegetal column between the two birds.

The benefit of looking at a large population of silks from a technical patterning perspective is that nascent developments in weaving technologies are evident by comparison with the main body of material. The study collection contains several examples of technical patterning steps toward more advanced weave structures such as lampas. Desrosier described early examples of the use of supplementary wefts to achieve design effects. CMA 1950 518 is an early example of such a weave.[76] Particular silks attributed to Spanish (CHMNYC 1902 1 978) or Islamic workshops (TMA 3 204, DO 2009 176 BZ1930 3) demonstrate a more active role for the ground weft in the composition, which is an important feature of lampas design.

BMFA 01 8342 and BMFA 25 reflect a different patterning experiment. The small diameter blue-dyed binding warp differs greatly from the thicker black main warp which seems to have been used in combination with the pattern weft to add relief to the figured design. TMA 11 30 demonstrates a technical innovation involving wefts. This figured silk portrays gold rabbits and leopards on a burgundy ground. Although now highly degraded, a few warps are intact enough to show that the silk is a 1/2 samite woven with highly twisted weft yarns. To maintain high twist when inserted into a shed, the wefts may have been coated with a substance that was later washed out. In the finished cloth, the effect of highly twisted wefts would have been a luxurious textured cloth.

In defining developments toward lampas weaves, an important silk in the study collection is DO 177 BZ1929 101. This white monochrome tabby-tabby lampas silk survives

[76] Desrosiers 2004, 263-309, esp. 23-25, 267-268.

in three fragments. The fragments demonstrate patterning by the effect of reflected light on contrasting floats in the interplay between the ground and main structures. Becker demonstrated how the 'pseudo-damask' forerunners of this monochrome silk could have been woven on the same looms and with the same tie-ups as those used for bi-colour and polychrome figured weaves.[77] Consequently, monochrome pattern weaves were probably woven coincidentally with bi-colour and polychrome figured silks rather than as a later development.[78]

b. Pattern summary

The weft-faced compound weave structure is based on repetitive design production. Used together or independently, orientation and symmetry provided adaptations to the form and limitations of loom-based patterns. While some early examples of silks were woven parallel to the warp, the large majority have a perpendicular orientation, effectively comprising a design standard. The use of horizontal mirror symmetry and vertical one-way pattern direction represented a second convention. Mirror symmetry explains the dominance of certain representational design forms including double-headed birds, central vegetal motifs, and paired animal or human figures. Silks with large-scale, one-way central figures were a conscious break with convention as a way to designate an elite textile and create a technical barrier to imitative reproduction.

Other design standards included the relationship between the ground and pattern colours, use of dyed warps, consistent warp step proportions, and curve gradation. Pattern tie-up faults were common and are among the most apparent determinants of quality. The role of hierarchy and workshop quality is especially evident in analysis of superficially similar patterns. Even

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[77] Becker 1987, 118-129; Schorta 1997; Schorta 2001.
[78] Becker 1987, 118-129.

in the absence of complete pattern units, detailed images of common features demonstrates the role of imitation and reproduction in the dissemination of pattern designs and weaving technologies.

7.5 End Use Data

Unlike the process stages discussed above, end use information is more limited in surviving textiles because of the fragmentary condition of remains, as well as the lack of secure find context. Some of the silks in the collection contain evidence that indicates particular functions. End use data include signs of application to garments, seams, shape, size, and wear. Presence of debris from earthen inhumation burials is suggestive, but difficult to categorise in a meaningful way.

Among the Mediterranean and Near East weft-faced compound weaves in the collection, thirty fragments contain specific evidence of having been applied as decorations on garments recovered from cemeteries based on fold lines and stitch marks. The shape and size of an additional nine pieces suggest that they were also applied to garments. Among the silks in the study group, two are still attached to a base fabric. BMFA 26 348a comprises three purple squares sewn to a yellow silk tabby weave base, the only such example in the study group. BMFA 01 8342 is roughly stitched to a tabby weave linen fragment. The right side of the band was turned under and sewn with coarse overcast stitches while the raw edge remained visible on the left.

Application of silk fragments to garments presents a mixed picture. In many instances, the representational motif was centred and symmetrically balanced before it was applied to the base. The designs on some other fragments were less well suited to decorative use. Several pieces were not centred or aligned when affixed to a tunic, possibly as a means of reusing parts of a worn textile. The size and spacing of the overcast stitches used to sew the decoration to the garment was often uneven, whether from lack of skill or in haste to prepare a body for burial. Sewing thread is visible on at least fifteen fragments and is generally two-ply silk. The limitation of using sewing thread as a characteristic is that it could have been added post recovery for reasons including display and mounting.[79]

The size of two fragments attributed to Egyptian cemeteries makes then unlikely to have been applied to tunics as decorations. Both CMA 1983 139 and TMA 11 21 survive in widths greater than 32 cm. Neither piece has marks indicating folds or sewing. The diagonal 'vine pattern with birds' design is continuous, without a central motif, and would have been particularly suitable for furnishing purposes, such as a curtain or bed cover. The size and condition of these silks suggest that they were used to wrap a body for burial. An additional nine silks do not show signs of having been sewn to garments, but appear to have come from Egyptian cemeteries based on condition and technical attributes similar to fragments applied to garments.

Unlike applied decorations, some fragments indicate that they were tailored for garments. A notable example is TMA 11 11 which shows a neckline and shoulder join. TMA 11 12 is a different silk, but may have been part of the same garment as the corner of a coat. The piece was lined and has an edge stitched to create a 'scalloped' decorative effect. The shape of BM 18958 1032 suggests that it was part of a shoulder or sleeve piece, which is supported by the appearance of running stitches along what would have been a shoulder seam.

Kelsey 22683 comprises two different silks that are seamed together. The fragments have similar motifs and were clearly woven on the same or similar looms, but with different

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[79] For displays by collectors, see chapter 5.3.

colours and decorative effects. The red ground fabric has a third colour weft inserted in bands. The blue fragment has no inserted third weft, but the small circular motifs have slightly different interior designs. Although we do not know why the two pieces were sewn together, the implication is that the same producer modified an existing design to provide superficially different cloths for the consumer market.

The small size of fragments from at least four silks in the British Museum suggests reuse for reliquary purposes. BM 1895 8-10 15 7 consists of eight small oval shaped fragments, the largest of which is about 6 cm wide and 10 cm long. Four of the pieces are seamed, combining two different cloths into one fragment. These were apparently cut from a larger seamed cloth and pressed flat. The warps on the joined fragments run in different directions indicating that the joined fabrics were not carefully pieced together. Three other British Museum silks: BM 1907 7-17 1, BM 1895 8-10-20-31, and BM 1895 8-10 33 comprise one, two, and six small fragments respectively. CMA 1974 97 was cut to a small size and shape which suggests reliquary use. CMA 1974 102 is a reliquary bag that measures 22 by 11 cm.

In addition to the seven silks in the collection that appear to have come from shrines based on physical characteristics, eight of the nine weft-faced compound weaves now in the Cooper Hewitt collection probably came from shrines such as the tomb of Saint Bernard Calvo, Bishop of Vich (d. 1243).[80] These fragments were part of Badía collection purchased in Barcelona by J. Pierpont Morgan and are among the largest and best-preserved silks in the

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[80] See chapter 5.1 fn. 30 and fn. 31.

collection.[81] In the end, however, the limitation of end-use analysis for the collection is demonstrated by the fact that 25% of silks lack any discernable usage evidence.

7.6 Classification system

As demonstrated above, a major benefit of studying a large body of weft-faced compound weaves on a comparative basis is that production patterns and technical developments are more apparent. To interpret the study group, silks were assigned to one of eighteen categories based on five technical characteristics: weave structure, weft insertion sequence, number of main warps, twill direction, and colour use or other special attributes as shown below (see appendix 7.2 for individual textile data):

Grp. No.	Category	Silks	Sub-groups
1	Samite - alternate - single main warp - S twill - design parallel with warp	3	2
2	Samite - alternate - single main warp - S twill - very fine warp and weft	1	1
3	Taqueté - alternate - single or multiple main warp - bi-colour or polychrome	3	3
4	Samite - alternate - single main warp - S or Z twill - non-representational	5	3
5	Samite - alternate - single main warp - S twill - bi-colour	7	4
6	Samite - alternate - single main warp - S twill – polychrome	9	4
7	Samite - alternate - single main warp - Z twill - polychrome	1	1
8	Samite - reverse - single main warp - Z twill - bi-colour	25	9
9	Samite - reverse - single main warp - S twill - bi-colour	3	2
10	Samite - reverse - single main warp - S twill – polychrome	4	4

[81] Guerin 2012, 117-118.

11	Samite - alternate - multiple main warp - S twill - bi-colour	5	2
12	Samite - alternate - multiple main warp - S twill – polychrome	2	2
13	Samite - reverse - multiple main warp - S twill - bi-colour	2	2
14	Samite - reverse - multiple main warp - S twill – polychrome	12	6
15	Samite - reverse - multiple main warp - Z twill – polychrome	1	1
16	Samite - reverse - single main warp - 1/3 S twill - with metal foil	1	1
17	Samite - alternate - multiple main warp - S or Z twill - no twist binding warp	2	2
18	Samite - reverse - single main warp - S twill - design parallel with warp	1	1
	Total:	87	50

This definition of categories on the basis of structural characteristics is a departure from the now out-dated scheme that combined alleged find spots with some descriptive characteristics.[82] This structural approach continues the methodology presented by Desrosiers and provides a basis for technical documentation independent of art historical interpretation.[83]

Within each category, data for materials, weave, and pattern attributes were analysed to identify relationships among fragments. Material characteristics include: binding warp colour, binding warp diameter, main warp features if different, the ratio between warp and weft diameters, the ratio between weft diameters, and the incidence of alternate weft diameter thickness. Textile data involve twill direction, the ratio of binding to main warps, weft insertion sequence, colour insertion order, average warps and wefts per cm, and the ratio of the two averages. Pattern unit features are compared by the number of weft colours, the use of interrupted colour wefts, observable pattern unit dimensions, pattern warp and weft steps,

[82] For a description of the attribution scheme, see chapter 5.6 and appendix 5.3.
[83] See Desrosiers 2004, 465-469.

average pattern step distance, and the ratio of average binding warp diameter to warp step distance.

Based on these detailed measurements, a total of fifty technical subgroups were identified. These subgroups represent characteristics that indicate similarities and differences in the choices, methods, and technologies involved in weaving figured silks. The common characteristics associated with each subgroup represents the most definitive definition of ‘workshop signature’ developed to date. The conclusion drawn from this analysis is that there were probably many different production centres that operated at various times in the region.

To establish the number of different textiles in the study group, data were evaluated for commonalities in terms of four types of relationships: divided fragments from the same loom, related textiles in terms of structure and design, similar structures, and similar designs. Based on these defined relationships, the collection includes thirteen divided fragments.[84] Adjusting the total number of Mediterranean and Near East weft-faced compound weaves in the collection for divided textiles results in eighty different Mediterranean and Near East weft-faced compound weave silks in the collection.

Within the study group, a total of twenty-seven fragments show evidence of related design. For some groups, the design and technical relationship among silks is close. For the ‘Amazon rider’ silks and the ‘vine lattice with birds’ fragments, technical data for materials and weave characteristics show close correspondence with all attributes reproduced. In the case of the ‘Samson’ and the ‘noble rider’ silks, there is less design and technical correspondence. The small fragment of CMA 1974 97 was drafted at a different scale than

[84] CMA 1947 192 and DO 168 BZ 1939 32; Kelsey 94151 and TMA 11 23; BMFA 01 8342 and BMFA 25 159; BMFA 26 348a, BMFA 26 348b, and BMFA 26 348c; Yale 1947 201g and Yale 1947 201h; and Yale 1947 201i and Yale 1947 201j.

DO 163 BZ 1934 1. Side by side comparison of the two fragments (appendix 7.14) shows that the silks share a similar reference, but were produced by entirely different pattern tie-ups. As shown in appendix 7.3, DO 165 BZ 1956 2 follows the same technical conventions as BM AN34973001 with respect to horizontal, and probably vertical, symmetry, but with more design variation including drafting differences and resolution.

Correlating categories with available end use evidence, cemetery silks come from at least nine different categories, indicating that there were probably several different workshops that provided material for the Egyptian market. Among these, forty-one of fifty-two fragments are bi-coloured. While only seven fragments were woven with multiple main warps, twenty-nine fragments display the work savings weft insertion sequence. The fourteen shrine silks and Badía collection pieces are assigned to nine different groups. Only three of these silks are bi-coloured. The twenty-one silks without evidence of either cemetery or shrine survival cover twelve categories. This correlation of silk type by available end-use information provides an additional perspective on the incidence and distribution of producers as having been widely distributed.

Among all silks in the study group, the four pieces in category 14a (samite-reverse-multiple main warp-S twill-polychrome) share basic similarities to silks attributed to the imperial silk workshop through inscription evidence. Based on published studies, the material and textile characteristics are similar with Z twist binding warps, 1/2 samite binding structure, 1:2 binding to main warp ratio, and reversing insertion sequence.[85]

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[85] For all measurements pertaining to the imperial silks, see: Muthesius 1997, 34-43. For the 'imperial elephant' silk, see Vial 1961; for the Siegburg lion silk, see Brachwitz 2002; for the Cologne lion silk, see Wilckens 1991.

While the basis for comparison is limited by the difference in investigative methods and the small number of silks in the imperial group, there are some notable differences. First, the imperial silks have higher densities in both the warp and weft directions. The imperial fragments have about 18 to 20 binding warps and 36 to 60 weft passes per cm. In comparison, the category 14a silks have an average of 14 binding warps and 34 weft passes per cm, resulting in a looser weave.

Second, the pattern unit size of the imperial silks is much larger than the comparable study group silks. Published width measurements for the 'imperial elephant' silk report a width of 78 cm;[86] 'imperial lions' range from 48-80 cm.[87] In comparison, the largest width pattern unit in category 14a is the CHMNYC 1902 1 221 elephant silk with a pattern width greater than 42.7 cm, followed by the CMA 1950 2 double-headed eagle with a pattern unit width of more than 26.8 cm. This comparison shows that the patterning capabilities of the imperial workshop looms far exceeded the demonstrated capacity of even the most impressive silks in the study group.

A third characteristic for comparison is the use of colour. Each of the group 14a silks use between three to five colours on a continuous basis. The 'imperial elephant' is known to contain five colours throughout the pattern unit.[88] In contrast, at least one of the 'imperial lions' was woven with interrupted use of colour.[89] On the Siegburg lion silk, the ground and dominant pattern wefts were continuous, while a third colour was incorporated on an interrupted basis. Two different colour wefts were laid-in for the eyes only.[90]

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[86] Vial 1961, 29.
[87] Brachwitz 2002, 108-110; Wilckens 1991, 32.
[88] Vial 1961, 30 f.
[89] Brachwitz 2002, 110.
[90] Brachwitz 2002, 110.

Some of the most impressive silks in the collection integrated multiple colours on a continuous basis throughout a pattern unit. The fact that at least one ‘imperial lion’ silk used three colours on an interrupted basis demonstrates the point that a variety of factors need to be considered in making attribution judgements on technical grounds. Assuming that the ‘lion’ silks were woven in the imperial workshop, interrupted use of colour wefts fit design requirements and was more efficient from a production standpoint.

This analysis demonstrates that the fundamental difficulty in making attribution judgements based on the small body of inscribed silks is that we have no information about how representative they were of the textiles woven at the imperial palace or in private workshops in Constantinople. From a narrow point of view, and judged strictly on technical grounds, it appears that none of the eighty-seven Mediterranean and Near East fragments in the study group can be attributed to the imperial workshop. While palace looms apparently had the capacity to weave designs on a monumental scale in the tenth and eleventh centuries, it is unlikely that such large patterns would have been appropriate for all court needs. Equally, use of a narrow standard does not explain the evolution of technology for production that pre-dated the inscribed silks.

As discussed in chapter 5.5, the current framework for attribution and dating has its origins in the late nineteenth- and early twentieth-century antiquities trade based on alleged find spots. Dating is problematic for all silks in the study group because of the lack of a large enough body of scientifically dated material to establish a specific progression of technology developments based on textile characteristics independent of iconography and style. Considered collectively, the silk fragments in the study collection demonstrate a general progression of technology developments as discussed below. Equally, progress in the field requires recognition of limitations of current research tools in light of surviving evidence.

Instead of perpetuating speculative dating and attributions, this study provides an objective basis for re-definition of the Byzantine silk narrative by reframing the problem in terms of the social, technical, and regional influence of figured silks in the Byzantine world and beyond.

7.7 Conclusion

a. Silk and society

The silks in the study collection provide strong complementary evidence for production and consumption of silk as related social processes. Figured silks manufactured by professional workshops were shaped by client specifications as well as market factors. While whole articles of silk are rare, divisible use of the material made it relatively accessible to a wider segment of the population, beyond what would have been considered exclusive elite use. Usage evidence indicates that figured silks were highly valued, conspicuously displayed, and were reused in fragmentary form for trim and decorations.

From a production point of view, surviving textiles contain information about the work environment and methods of production. Close analysis reveals characteristics associated with workplace organisation, processing steps, demonstrated skills, division of labour, and work habits. Evidence indicates distinctive specialised roles for the designer, weaver, and assistant.

Among various attributes, it is the errors that provide the most intimate perspective on the working lives of weavers. The work was evidently exacting, especially the process of preparing the loom. While we can only judge from surviving finished textiles, the incidence of tie-up faults shows that minor and major errors were allowed to continue throughout a textile length. Some weavers faced equipment-related problems with uneven warp tension on their looms. The task of maintaining an even warp distance and weft density was on going. The difficulty of coordinating work between a weaver and an assistant is also obvious. Based on the study group, the overall impression is one of tedious and difficult work under time pressure with constant adjustments required to maintain the weaving process.

The textile evidence shows that a body of conventions existed that provided a means of standardising work. The high degree of consistency of certain practices over hundreds of years in widely separated workshops is a surprising finding from this analysis. The uniformity of twist direction and angle suggest that technologies associated with silk were transmitted with the material and adopted by specialised producers at various locations throughout the region. While patterns varied among textiles, particular design conventions were applied to the majority of silks in the collection.

In terms of structure, 1/2 samite was overwhelmingly the dominant method of patterning silks. Pairing a twisted warp with an untwisted weft meant that each component had a specific function that was adopted by producers with variation only in instances when a particular effect was desired. Differences occurred in incidental decisions such as the choice of either twill direction or in colour insertion order. The highly repetitive nature of weaving lends itself to formation of craft habits that were presumably shared by weavers within a given workshop.

Economic motivations are evident in surviving fragments. The widespread adoption of the work savings method of returning weft insertion demonstrates an efficiency innovation that reduced the labour involved in weaving complex silks. The use of lesser quality dyes in warps was a means of economising on materials while disguising visible warps. Substitution of lower quality or spun silk implies either economy or fraud. Interrupted use of colour provided the appearance of a more expensive polychrome silk without the associated costs.

b. Silk and hierarchy

Although structurally similar, the appearance of the weft-faced compound weaves in the study group varies enormously. Products ranged from complex compositions to imitative reproductions, apparently in response to consumer demand. The silks show that representational content alone does not provide a basis for qualitative differentiation. The collection includes several examples of sophisticated and lesser quality pieces that share similar motifs as well as original and debased versions of the same pattern.

The most visible attributes that distinguished high status figured silks are colour, pattern design, scale, and weaving quality. One insight from this analysis is that an original pattern design was effectively a form of 'intellectual property' associated with a particular workshop. The designer was confronted with the problem of integrating materials with existing labour and loom equipment. A successful design had to be recognisable and artistically rendered in a pattern that was adapted to the constraints of a grid-based design with appropriate resolution and a limited number of colours. The time required to tie-up a pattern harness was substantial, especially for large and complex patterns. Given the investment required, it is reasonable to expect that patterns would be reproduced over a long interval. Use of a large scale, one-way pattern design requiring a loom with a suitable pattern harness provided one of the few means available to limit imitation.

Production of a high quality silk did not necessarily mean the absence of all errors as they would be recognised today. Efficient workshop production meant making certain trade-offs such as bare warps caused by returning colour wefts and faulty coordination between weavers. These were made less noticeable by dyed warps and pattern design. Considered in terms of material, structure, and pattern design, the evidence suggests that high quality figured silks required a supervised work setting to coordinate work and to organise specialised resources including equipment, materials, design capabilities, and skilled weavers.

c. Silk and regional exchange

A benefit of technical analysis of a large population of silks is that the on-going process of differentiation and imitation through production and consumption is more easily discernable. The evidence indicates that textiles themselves provided a vehicle for the transfer of weaving methods and techniques among workshops throughout the region. While technical analysis alone does not provide a secure basis for dating surviving fragments, the collective body of material demonstrates technical progression in an on-going process comprising a series of independent developments that were gradually transmitted among producers.

The earliest attributed examples were woven with an alternate insertion sequence and a design parallel to the warp to reduce the pattern width. Use of separate warp beams or other devices allowed tension to be maintained on each warp. Introduction of a reversing insertion order reduced the time required to weave figured silks, but presented the problem of how to manage multiple colours. Use of multiple main warps expanded the patterning area of a single weft pass and decreased lateral deformation. This innovation maintained the structural integrity of the 1/2 twill structure, but reduced the relative visibility of the binding warp with a general trend toward a less dense weave.

While well suited for pattern design, the weft-faced weave structure had certain disadvantages that contributed to continuing weaving innovations. Unlike a balanced weave with equal spacing of yarn components, maintaining consistent pattern height and width was a problem for all workshops. Only bi-colour silks were two-sided. In polychrome silks, expensively dyed silk wefts were hidden from view until they came to the surface as required by the pattern, making the structure an inefficient use of materials and labour. As compared with samite and taqueté, lampas represented a superior structure to introduce light and colour effects in a balanced weave. Double weave provided a cleaner line for patterning and a fully reversible textile. While specific dating is uncertain, the textile study group suggests a general trend toward internationalisation of general techniques with a greater scope for differentiation and specialisation at particular locations. The following chapter synthesises the complementary evidence drawn from written sources and this analysis of textile fragments.

CHAPTER 8: CONCLUSION

8.1 Research Summary

From a regional Mediterranean perspective, the transformation of silk production and consumption patterns from East to West during the first millennium represented a social and technological process of adoption, application, and adaptation. The many favourable properties of silk – smoothness, fineness, lustre, dye-receptivity, durability, drape, strength, and elasticity – had an important role in shaping the textile material culture of contemporary societies. While historians generally agree on the broad outlines of this process, the conventional understanding of silk as an exclusive material confined to court use in middle Byzantine society is inconsistent with the body of evidence.

As discussed in chapter 1, this work was devised for the purpose of establishing a more comprehensive interpretation of silk in the middle Byzantine period through examination of production and consumption evidence. The research approach was framed in terms of overlapping themes comprising the role of silk in society, a hierarchy of valuable fabrics, and integration of Byzantium in the regional textile economy with evidence from textual sources and textile remains considered on a parallel basis. The long-term historical process involving silk was shaped by a continuing cycle of elite differentiation and imitative reproduction.

Chapter 2 demonstrates how Byzantine writing conveys the importance of silk to the empire during the full extent of its history. In early Byzantium, a series of laws were issued to restrict the manufacture and use of silk to the state. Following the crises of the seventh and eighth centuries, silk was among the resources rationalised for imperial purposes. Sources describe the ways silk was employed by the state in various ceremonial, diplomatic, and economic roles. Representational pattern weaves were prominent as a vehicle to project meaning, rank, and status. Specialised palace workshops supplied the quantity and type of material required for imperial use. Imperial prerogative concerning silk was defined and enforced through regulation of the private silk industry in Constantinople. The economic and social changes that occurred in the eleventh and twelfth centuries indicate a changing environment for silk production and consumption.

While Byzantine historical analysis has advanced in many areas related to material culture studies, chapter 3 defines some of the factors that have inhibited research. Unlike some Islamic and Genizah compilations, a systematic survey of Byzantine texts for textiles has yet to be produced. The scattered and fragmentary nature of source evidence limits the applicability of conventional historical research methods. Difficult terminology and the cross-cultural character of textile interactions represent other obstacles with few scholars now active in the field.

Chapter 5 describes the circumstances that led to the survival and recovery of textile fragments and how they came to be held in hundreds of museum collections. The lack of secure find and contextual information for all but a few survivors represents a formidable research challenge. The interpretations of some early researchers have been carried into the present with many attributions lacking a critical basis. While art historical methods are well suited to the body of surviving remains, fragments are too poorly situated temporally and geographically to support specific conclusions.

The technical textile scholarship associated with this material is mainly confined to piece-specific analyses of the most intact and impressive surviving examples presented in specialist publications. The lack of comprehensive collections surveys and standard technical analyses accompanied by quality images has meant that available evidence has been selectively considered. The fragility of surviving silks means that high conservation standards for the material are a necessity. The unintended consequence is that access is effectively limited to all but a few researchers with the requisite skills to interpret the evidence. Crucially, the field lacks a resource that synthesises technical features and interprets evidence in a form accessible to non-specialist historians and textile researchers.

Despite the challenges, the quantity and variety of source material represented an opportunity for a fresh approach with the aid of methodological advances and application of computer tools. The research framework applied to this work was defined in terms of assessed requirements comprising comprehensive and balanced treatment of sources, use of methodologies appropriate to the nature of evidence, and cross functional interpretation to integrate textual and material remains.

While ostensibly related, silk remains and textile textual mentions have very different characteristics requiring a common basis for analysis. A framework structured in term of silk textile production stages provides a means to integrate the bodies of evidence. These include fibre and yarn preparation, textile construction, pattern reproduction, and the end-use of finished cloth. Other relevant evidence includes quality characteristics and planning decisions. A strategy for data collection was defined to ensure specific, comparable, and reproducible data. The intention was to take advantage of the relative context provided by each of the respective bodies of evidence for the purpose of comparative analysis.

Chapter 3 shows how prosopography provides a method of aggregating the fragmentary and scattered data associated with textiles into a consolidated resource. The resulting textile mention database provided a structured approach to data analysis with the advantage of relational design to organise and access information for focused textual analysis. Chapter 6 documented the process of developing a non-invasive research protocol based on high-resolution macro and micro scale digital images. A specialised computer vision application created for the purpose of this project provided the informational tools necessary to obtain valid measurements for defined attributes.

The analysis presented in chapter 4 is based on a corpus comprising over 800 descriptive mentions of textiles found in twenty-two Byzantine texts dating from the sixth to thirteenth centuries. Information from Byzantine sources is supplemented by relevant mentions found in contemporary Islamic texts and some Genizah documents. Analysis of silk terminology shows that references were mainly inferential with meaning conveyed through contextual clues such as colour, embellishment, superlative description, and setting. Although *serika*, *blattia*, and *metaxa* were all names for silk, each has a distinctive identity as shown through usage patterns. In addition to reporting events associated with silk, Byzantine historians frequently used textile objects for symbolic representation or to give figurative meaning to their writing.

Analysis of textual information on a consolidated basis indicates that trade in silk fibre involved active cross-regional exchange and specialised roles for grading, buying, and processing the material. Mentions of gold yarns and embellishments were prominent in the written sources of all cultures included in the analysis. References to various textile occupations and the names of particular fabrics provide details about production and consumption of luxury goods and cloth items in common use. Evidence associated with pattern details is particularly illuminating because elements of aesthetic perception and symbolic representation coincided closely with other forms of imperial media. Detailed examination of sources provided a basis for definition of the terms *di*- and *triblattion* and coincidental imperial use of monochrome patterned 'damasks' as determined by ceremonial needs. Interpretation of data for end-use draws on the concept of 'brand' to show how analysis of textile names, especially those with a geographic basis, can detect attitudes and preferences for particular types of fabrics.

Chapter 7 presents the results of my analysis of 125 textile fragments from ten museum collections provisionally dated between ca. 600-1300. As is typical for this class of artefacts, none of the fragments came from a known or dated context. According to my research protocol, I documented these textiles with a total of 10,635 images. These comprised the study group of silk textiles for this work. Based on maximum width and height measurement, the total area of the textile fragments analysed is more than 780 metres. Most pieces in the collection were woven exclusively with silk; gold is visible on just nine fragments, six of which were woven with the true lampas structure attributed to the twelfth to thirteenth centuries.[1] Two textiles have Greek inscriptions, and five display kufic or pseudo-kufic script. Technical analysis demonstrated that the weft-faced compound weaves structure was the dominant method of patterning silks with ninety-four examples. Of these, eighty-seven are attributed to Near East and Mediterranean centres. Conservation conditions vary widely, but most silks show significant signs of degradation and loss.

Yarn analysis demonstrated a number of common component attributes, notably the near uniform use of Z twist binding warps and consistent angle of twist around 13 degrees. Weave analysis showed the dominance of the 1/2 binding structure with just one exception. For the purposes of this study, errors are informative because of the process information they convey. All of the weft-faced compound weaves included in the study group contained at least some faults. Types of errors discussed in this work include yarn defects, binding and main warp tie-up mistakes, uneven weft diameter, inadequate warp tension, incidence of bare

[1] See chapter 6.1 and Schorta 1997.

warps because of coordination mistakes or polychrome colour use, and uneven warp and weft densities.

To produce patterned weaves, designers adopted a similar set of conventions that coincided with the choice of weave structure. Although very fragmentary, end-use data provide some perspective on the distribution of material between cemeteries and shrines in terms of the number of different producers. Considered collectively, information obtained from silk fragment analysis provides insights about the professional production environment, workshop conventions, use of technology, and the organisation of work.

8.2 Combined Analysis

In keeping with the framework devised for this study, the following analysis compares data synthesised from textual evidence and silk remains for analysis of material, textile, pattern, and end use characteristics.

a. Material

A major contribution of this research is to demonstrate the value of studying material components involved in silk textile production. Written sources and textile remains contain complementary information that has not been interpreted from a Byzantine perspective to date. As discussed in chapter 4.2, silk fibre was not an undifferentiated product, but consisted of many grades and types, each with recognised properties and qualities. As dealers in raw silk, the *metaxopratai* applied their expertise to inspect and grade the raw silk fibre coming into Constantinople for the wholesale fibre trade.

While survival conditions of textile remains vary considerably, the composition of silk yarns reflect some possible qualitative distinctions based on direct observations. Compared to Mediterranean and Near East weft-faced compound weave silks, fragments attributed to East and Central Asia have fibres that are notably smoother and more uniform in quality.[2] These characteristics are distinct from evidence for wear.[3] While such differences may be associated with survival context, the observation pertains to most silks attributed to Mediterranean and Near East production centres. What is not known is whether qualitative differences stem from inferior fibre properties or processing at some production process stage. The same qualification pertains to the 'hairy' silks noted in the study collection.

There is a high degree of correspondence between textual and material evidence to demonstrate that silk yarn processing was a specialist occupation. Chapter 7 of the *BOE* referred to the guild of the *katartarioi* as processors of raw silk.[4] As discussed in chapter 4.1, other sources confirmed the specialised skills associated with fibre and yarn preparation. The nearly uniform choice of Z twist direction combined with consistent warp twist measurements among textiles with different attributed dates and production locations is a significant finding. This characteristic confirms that work performed in yarn preparation occupations was fibre-specific for silk since the choice of twist direction differed from established craft habits in some locations. The results suggest that the material, equipment, and techniques were all transmitted coincidentally throughout the region.

Textual sources and silk fragment remains confirm that the market for silk was highly developed with a range in products that differed widely in form and quality. The evidence shows that silk was not confined solely to exclusive products for elite members of society, but existed in forms suitable for a range of customers and uses. In chapter 4.1 the textile mention database analysis demonstrated that spun silk was a near substitute for silk filament yarns. This evidence coincides with the finding that at least two of the silks in the study collection

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[2] For silk fibre observations, see chapter 7.2.
[3] Cooke and Lomas 1990; Hearle, Lomas, et al. 1998.
[4] *BOE*, Koder, 7.1.

have spun silk warps that were strengthened to withstand loom tension by plying. While we have no information about the relationship between the producer and consumer for these textiles, the fact that one fragment had a visible filament silk binding warp and an invisible spun silk main warp suggests that either economy or fraud were involved.

By necessity, the scope defined for this study was limited to patterned silk textiles. As noted in chapter 5.7, archaeological finds include silk incorporated with other fibre types. The textile mention database contains numerous references to half silks that comprised a category of products in its own right with various qualities and grades. Textual sources and surviving evidence clearly demonstrate that silk was a divisible luxury available in some form to a broader segment of society. The hierarchy associated with silk fibre was based on a combination of quality, processing, and quantity characteristics. Byzantine, Islamic, and Jewish sources all suggest that the supply of silk in the region grew over time in response to increased demand for the material. Surviving silk fragments support this interpretation, but the lack of a large enough body of securely dated material limits more specific findings.

The structured approach to this analysis provides a means of assessing the representativeness of material remains as well as identifying lacunae. The small quantity of gold in weft-faced compound weaves represents a significant discrepancy in the survival evidence as compared with textual sources. The database analysis demonstrates the prominence of gold in imperial contexts to display wealth and status, as well as for decorative and aesthetic purposes. The *BOC* describes the ways that gold was applied to textiles including weaving, embroidery, and gilding.[5]

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[5] For details associated with use of gold described in the *BOC*, see chapter 4.4.

The find of gold interwoven silks at Amorion indicates that gold yarns were not exclusive to the most elite members of society in Constantinople.[6] Similarly, references to gold textiles are abundant in Islamic sources. Analysis of Genizah marriage contracts shows woven textiles decorated with gold were affordable by some middle-income brides. The two instances of gilded yarns in the study group demonstrate one way that metals might have been incorporated into textiles without use of more costly yarns made from gold foil.

The structural limitation of metal yarns in weft-faced compound weaves as described in chapter 7.2 may partially explain why gold was never mentioned in reference to imperial quality figured silks such as *di-* and *triblattion*. From a technical perspective, metal yarns are better suited to lampas weaves as demonstrated by the six surviving gold lampas textiles in the study collection. The prominence of gold in the written sources considered in this work suggests that many metal-embellished textiles were melted down to recover the material for re-use. As noted in chapter 4.2, the alleged intention of Michael III to melt imperial garments containing gold indicates that the practice existed, even if the particular set of garments in this instance were spared. Chapter 5.2 refers to some fifteenth- and sixteenth-century accounts for St. Peter's in Rome that document the destruction of precious metal cloths found in high-status tombs to recover gold.

b. Textile

By nature, the labour-intensive work necessary to produce well-executed complex weave figured patterns requires a hierarchically organised structure to plan and coordinate work as well as to supervise skilled workers. The combined evidence from textual sources and textile remains provides complementary information about production practices. Chapter

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[6] See chapter 5.7 for discussion of excavation finds at Amorion.

2.3 examined available evidence concerning the imperial silk workshop in terms of its administrative structure, location, and the identity of workers. While social information is fragmentary, sources suggest a professional workforce comprising free men and slaves in a hierarchical organisational structure. Analysis of the regulations contained in the *BOE* shows that *ergasterioi* combined the help of their families with the labour of others, including apprentices, slaves, and paid workers of varying skill levels who were hired on a contractual basis.[7]

The *serikarioi* participated in at least three distinct textile-processing activities: dyeing, weaving, and tailoring garments for sale to the *vestipratioi*, the silk garment merchants. Other written evidence shows that these were each specialist occupations, and oversight to plan and coordinate work. Chapter 8.11 of the *BOE* recognised these skills by imposing a harsh penalty for the loss of a skilled pattern weaver to a foreigner. Other regulations governed the terms of employment for hired workers.

The detailed study of silk fragments presented in chapter 7.3 confirms the hierarchical nature of the work and the need for planning and coordination. To produce a quality textile, persons involved in the production process had to coordinate work efforts on a consistent basis. Although workshops were widely distributed, the material and structural conventions associated with samites were widely adopted. Producers apparently understood the performance attributes of the weave because surviving fragments differ principally for choices that did not affect the appearance of the finished product such as twill direction and colour insertion order.

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[7] See chapter 2.4 for regulation of private silk trades and chapter 4.3 for analysis of *serikerioi.*

In the labour intensive and error-prone process of weaving weft-faced compound silks, measures to increase production efficiency and reduce labour content are evident. These include use of multiple main warps to expand patterning area, which has the advantage of expanding the width of a pattern element for the same amount of work. Adoption of the reversing order of weft insertion was a major efficiency innovation by reducing the number of changes in the pattern harness. This innovation also created new types of faults that affected the quality of finished goods, but seem to have been accepted by producers as a concession to faster production.

Textual sources and textile remains provide complementary information concerning fraud in the silk trade. Some *BOE* regulations supervised transactions between sellers and buyers. The scope for fraud in the silk trade was large and existed at each production stage. As described in chapter 4, textual sources refer to price fixing, rigging of scales, fibre adulteration, and misrepresentation of materials and products. Surviving textiles suggest either economy or fraud with inferior dyes, inconsistent quality, and interrupted use of colour.

c. Pattern

Both textual mentions and material remains show that representational woven pattern silks provided a versatile and portable means of visual communication in the Byzantine world. The close iconographic correspondence of figured patterns involving animals is striking, especially for birds. A combination of factors may have contributed to the dominance of certain types of representations including symbolic importance, design characteristics, and the nature of description in the written sources included in this analysis.

Chapter 4.4 refers to art historical studies suggesting that birds conveyed exegetical meaning as symbols for saints and martyrs. As discussed in chapter 7.4, choice of subject was also influenced by technical pattern considerations. Bird motifs were meaningful, but also recognisable when depicted on bi-colour silks. Large-scale, double-headed birds, such as eagles or peacocks, appeared impressive in designs that used mirror symmetry to good advantage. The formal appearance of grid-based patterns was well suited to heraldic figures. Drafted in profile, exotic and mythical animals such as elephants, griffons, and senmurvs could appear powerful in a medium that made realistic depiction difficult. Vegetal and human figures are not as apparent in writing, possibly because they are less easily described, rather than from a lack of representation.

Use of strongly contrasting colour combinations has its basis in the structure of weft-faced compound weaves. Although some silks have suffered colour changes from fading or chemical reactions, many have schemes that are consistent with textual descriptions. Saturated colours in purple, deep red, and dark blue coincide with imperial accounts of murex dyes in purple, red purple and blue purple shades. Other attributes such as use of colour or value-matched warps made the light colour pattern images more readable.

A textile designer had to draft patterns that suited aesthetic and representational aims, but were also suitable for the available equipment, materials, and skills. Use of symmetry provided a means of reducing the work associated with pattern representation by doubling the width of the image. Pattern tie-ups constituted an investment in labour that was recouped by repetitive reproduction. Use of a different colour scheme combined with superficial pattern changes allowed a workshop to produce cloths with a different appearance from the same basic tie-up.

The research presented in chapter 7 suggests how imitative reproduction from patterned cloths provided a means of transmitting figured patterns among workshops. The designs analysed in chapter 7.4 indicate that a ‘primary’ pattern cloth sample provided a model for replication in a series of increasingly debased forms. This practice would have enabled production of figured patterns without the work involved in drafting an original design. The number of slightly different reproductions suggests that imitative reproduction was a response to consumer demand. One way of analysing workshop capabilities is to distinguish pattern originators from duplicators. Silks with large-scale, one-way central figures were a conscious break with convention as a means to indicate an elite textile and create a technical barrier to imitative reproduction.

d. End use

Written sources and textile remains recovered from cemeteries show that figured silks were used for some similar purposes, despite different social status. The sources discussed in chapter 4.4 described patterned silks for various types of imperial garments, furnishings such as cushion covers and curtains, and ecclesiastical use. Inventories and other non-imperial sources reported figured silks sewn into garments, furnishings, and for altar cloths and hangings. The evidence presented in chapter 7.5 showed that figured silks were sometimes made into tailored garments, but were more frequently used in a divisible form for tunic decorations. Fragments too large for garment decoration show signs of having been used to wrap a body for burial. The quantity of material and the type of design suggests that the cloths were originally used for curtains or bedcovers.

While some decorations were well cut and show signs of careful attachment to tunics, others suggest re-use from larger, possibly damaged fragments. In some instances, the motifs were not centred and were poorly sewn. The apparent re-use of silks for burial purposes coincides with observations from analyses described in chapter 5.7.

Investigation of end-use also demonstrates the problem of limited evidence. Silks recovered from European shrines reflect the values and priorities of the consuming culture. Given the durability of silks stored in certain conditions, the final form of some cloths may reflect re-use that occurred over many centuries. The international character of silk exchange meant that even a secure find spot might not provide evidence about the producing workshop.

Available end use information for surviving fragments is complemented by the perspective provided by analysis of textile names. The consolidated corpus demonstrates the value associated with production location as a brand identity. By aggregating data from various sources, patterns associated with certain textile types demonstrate wide circulation of various types of cloth. Reported preferences provide insights about how textiles were identified and varied in relation to each other. The premium associated with certain production centres appears to have offered assurance of quality, and provided incremental status to the consumer.

Compilation of a cross-cultural glossary of textile names and characteristics would provide an important resource to support identification of surviving remains. Some types of surviving textiles such as inscribed *ṭirāz* fragments were culturally specific to the Islamic world. However, the widespread exchange of materials and production methods suggests that material now classified as Coptic or Islamic could equally be considered Byzantine based on the texts discussed in chapter 4.

8.3 Research Questions

a. Social role of silk in Byzantium and imitation

Considered together, textile mentions and surviving fragments represent an exceptional body of evidence. At the outset of this project, I expected that written sources would provide some insights about specification and consumption, while data from silk fragments would be limited to production characteristics. To my surprise, I found that each type of evidence conveyed information about the interaction of supply and demand on the material culture associated with silk. The benefit of analysing a large body of data is that the on-going process of differentiation and imitation through production and consumption is more easily discernable.

Integration of evidence defines a historical process based on a specific material, and shows the evolving roles of silk in the empire. Although silk had been a valuable luxury product for centuries, the early Byzantine state restricted manufacture and use. As described in chapter 2.1, imperial prerogative concerning silk was defined in association with purple murex dyes and use of gold. In response to the crises of the seventh and eighth centuries, the evidence presented in chapter 2 demonstrates that silk was among the resources rationalised by the state to serve imperial purposes. The material was extensively integrated into the social and economic framework of the middle Byzantine court as a means to project imperial conceptions. The success of these collective measures as relayed through primary sources now defines the modern conception of Byzantine silk.

Despite its interests, the empire did not control international trade in silk, nor access to sericulture technology. Despite the perception that silk was an imperial monopoly, the material appears to have been widely available in Constantinople and elsewhere in the empire. The detailed study of silk presented in chapter 4 provides insights about the interaction of supply and demand the material culture of Byzantine society and the larger region.

As compared to other fibres, silk was considered to be relatively luxurious, but was only one factor contributing to the value of a particular textile. Not all luxury cloths were silk; some silk cloths were of a relatively low quality. Silk remained a luxury fibre on a comparative basis and was never common enough to displace wool and linen. Written and physical evidence both suggest that silk was affordable, at least in limited quantities, by persons of moderate means.

Complementary use of textual and textile remains provides information to define characteristics associated with silk processing activities. Evidence presented in chapters 4 and 7 show that silk production activities were specialised by function into defined occupations. Professional workshops were hierarchically organised for planning and coordination of work. Certain design and structural conventions provided a means of standardising work. Incidental differences may reflect transmission of craft habits within a particular workshop or culture area.

An insight gained through this analysis is the role of certain types of luxury goods in society. Elite use of silk stimulated imitative demand for the material. Increased fibre supply and development of various products made silk more widely accessible. Encroachment on imperial prerogative resulted in efforts to restrict access and to differentiate and elevate elite goods. The competing efforts of elite imitation and differentiation contributed to the transmission of the material and associated technologies throughout the region.

b. Textile hierarchy and differentiation

Since the material content of silk was not enough to make textiles exclusive, and imperial colours could be imitated with common dyes, two co-existing strategies for differentiation were applied in the middle Byzantine period. Embellishment with valuable materials such as gold and gemstones was an obvious measure. Usage requirements and practical constraints limited the extent to which these could be employed.

The second means of elevating silks was through application of technology and organisation of work by weaving weft-faced compound figured silks. Drawloom production methods were adapted to weave silks patterned at a scale that was impossible to imitate by other methods, while allowing material to be produced in sufficient quantities for elite and ceremonial use. As demonstrated in chapter 4.4, *Triblattion*, *diblattion*, and *dimoiroxea* were imperial quality silks based on figured pattern weaves.

As illustrated in chapter 7, pattern weaving technology was not exclusive to the imperial workshop and figured silks spread throughout the Byzantine world and beyond. The repeating cycle of elite differentiation and imitative reproduction contributed to development of new weaving methods including lampas and double weave.

Chapter 4.4 discussed the hierarchical ordering of imperial silks in terms of high, middle and low categories, with subcategories comprising first, second, and third grades. The context of description indicated that recipients and observers understood the hierarchy associated with these weaves. Based on examination of the eighty-seven Mediterranean and Near East weft-faced compound weaves in the study group as discussed in chapter 7, there are no discernable technical or structural attributes that identify silks as belonging to imperial or sub-imperial categories. Characteristics such as colour, pattern size, representation, use of precious metals, garment type, or other finishing detail may have defined a 'qualitative hierarchy', but no evidence survives to support more specific definition.

c. Byzantium in the regional textile economy

The evidence presented in this work demonstrates that silk was a regional material in the middle Byzantine world. The favourable characteristics of silk led to the spread the material. By the tenth or eleventh centuries, silk fibre production was widely dispersed in the region, from Persia to Spain, with a large number of production centres producing fibre with different characteristics. Silk production, fibre processing, textile manufacture, and garment use could be widely separated. Silk weaving was not confined to a few imperial centres, and may have been widely distributed for the consumer market.

Silk patterned weaves were part of the relative hierarchy of textiles that included, but were not exclusive, to the luxury products enjoyed by elite members of society. Although the state tried to prevent production of imperial-style figured weaves, patterned silks were traded widely. Trade spread pattern weaving technology and led to new technical developments. The evidence indicates that textiles themselves provided a vehicle for the transfer of weaving methods and techniques among workshops throughout the region. Evidence shows that development of methods was not a simple or linear process, and occurred through interaction among producers in a long-term process of adaptation and innovation. The textile study group also suggests a general trend toward internationalisation of taste among connect populations with a greater scope for differentiation and specialisation at particular locations.

This project provides an example of how systematic textile research can provide insights into historical cross-cultural exchange. During the period covered by this study, there were many reasons for shifts in textile production locations including war, political upheaval, economic disruption, population movements and access to trade routes and materials. Given the evidence, the most pervasive factor of all was the historical process of imitation and appropriation.

d. Byzantine silk definition

Returning to the main question posed for this work, definition of Byzantine silk depends upon the frame of reference. In the middle Byzantine period, the imperial state successfully projected imperial concepts through silk as a state resource. Primary sources indicate that a combination of independent decorative choices involving colour, metal use, and patterning were part of an evolving Byzantine aesthetic that formed a powerful medium for display. As this study has shown, the Byzantine silk narrative is incongruent with written evidence and surviving textile fragments. Byzantium was closely integrated into the regional silk economy of the time.

Although patterned silks were highly visible in some primary sources, a woven representational design does not necessarily make a silk 'Byzantine'. Pattern weaving technology was widely disbursed throughout the Byzantine world and beyond. Careful analysis of written sources provides some specific information, but is not exclusive. Apart from a small body of inscribed silks, we lack evidence that supports specific workshop attribution by production location. To this end, progress will depend upon a combination of secure dating through objective methods and technical and art historical analyses.

Based on the findings of this study, Byzantine silk is best described as a social, cultural, and technical phenomenon that owes much to the imperial state, but is not defined by it. The technology for weaving patterned silks may have passed from Sassanian to the Byzantine imperial workshop, as well as other producers in the region, as a means of differentiating silk goods for palace and elite use. Unlike other luxury textiles that are less specifically describable, large-scale representational patterns are recognisable and distinctive in both written and representational sources.

The unlikely survival and transfer of a reasonably large body of material to public museums has shaped research approaches to date. Over time, changes in weaving technologies, popular taste, and court needs shifted production away from large-scale bi-colour and polychrome representational figured silks in favour of more differentiated types of silk weaves. While luxurious and desirable, these were less easily described in written transmissions. After the *BOC* in the mid-tenth century, we lack an imperial protocollary source documenting silk in official use until the *Treatise on the Dignities and Offices* (ca.

1347-1368).[8] Defining Byzantine silk in terms of its social, hierarchical, and regional roles provides a means to communicate the historical processes associated with the material.

8.4 Significance and contribution

The research strategy defined for this work contributes to the existing body of scholarship by providing a basis for consideration of relative evidence in order to detect patterns that are not readily apparent by conventional methods. The methodologies provide a specific basis for synthesis of findings in a form that can be evaluated and compared with research findings from other textile studies or types of artefacts. The general production stage framework comprising material, textile, pattern, and end use provides a structured means to analyse different categories of evidence that are related by culture, but differ in form.

One of the aims of this research programme was to provide an expanded basis for discussion of silk and its role in the material culture of the middle Byzantine period. The intention was to interpret the material in a way that is both accessible and meaningful to a broader community of scholars. This work has demonstrated that while silk was an imperial resource, it also had broader social implications. Identification of the process of elite differentiation and imitation of luxury goods provides a heuristic framework of potential value to other types of Byzantine material culture studies.

From the standpoint of economic history, textiles were an important industry in the Mediterranean region during the middle Byzantine period. The paucity of detailed evidence associated with Byzantine trade has long meant that the empire's role in the regional textile economy was not fully appreciated. The research presented here provides evidence about Byzantine commerce involving silk. Of particular benefit are insights about how textile

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[8] Pseud Kodin.

technologies were exchanged among workshops and how work practices evolved with changing patterns of consumption and production.

For art history, figured textiles provide a means to interpret silks in terms of representation and other contemporary media. This work contributes insights into the evolving relationship among symbols, textile design, and technology. Art historical analyses involving silk need to consider how content, presentation, and repetition were influenced by drawloom characteristics. Although the form of textile remains does not, as yet, support specific workshop attribution, various technical attributes suggest that that many production centres existed with different capabilities.

As a cross-disciplinary study, this research programme benefits the field of textile history in several ways. The research approach integrates different forms of historical information according to specific and objective characteristics. An important contribution is to demonstrate the role of textiles in the larger historical process from the standpoint of both Byzantine history and regional economies. The field of textile research faces the on-going challenge of synthesising findings in a way that can be interpreted by a larger body of scholars.

The characterisation methods for silk remains developed for this work are applicable to other types of archaeological textiles. Textiles provide important evidence of technology developments over time, but are difficult to assess on a comparative basis. Consideration of evidence in terms of production stages provides a means of detecting and analysing various processes from material preparation to end-use. This work also demonstrates how use of digital representations can aid in the examination, analysis, communication, and interpretation of artefacts. Ideally, the imaging methods developed for this project can improve access to the material for researchers with the hope of increased participation in order to advance technical research in the field.

8.5 Next Steps

The research involved in this work identified a number of research opportunities that are a direct extension of this project. First, for textile mentions, inclusion of more source evidence would surely produce new insights about the role of cloth and its production to various aspects of Byzantine life. An area for additional research pertains to symbolic and metaphorical references to textile objects. The Byzantine sources discussed in chapter 4 demonstrate the importance of cloth and garments to identity that has not been adequately explored. The silk cultivation practices alluded in the fourteenth-century didactic poem by Manuel Philes deserve further study for comparison with other contemporaneous Mediterranean cultures.[9]

Second, while specific definition of textile terms is difficult because of the dynamic nature of the lexicon, integration of contemporaneous references and contextual information can aid in interpretation. Publication of a glossary and analysis of textile-related terms including colours, dye stuffs, materials, weave types, and textile names would be a valuable contribution by making references more meaningful to historians. The long-standing importance of Serjeant's compilation of primary references to textiles from Islamic sources demonstrates the potential value of a similar resource for Byzantine studies. Integration of textile information from neighbouring cultures such as Armenia could also provide new information to the field.

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[9] Animalibus.

Third, this work has demonstrated the value of non-invasive high resolution imaging for technical textile research. While not all structures are suitable for application of this method, more information can be gained from documentation of weft-faced compound weaves in other collections. While this non-interventional research methodology does not completely replace first hand technical analysis, it provides a means to take advantage of limited study time by focusing on types of information not easily captured through photographic documentation.

With appropriate permissions, a fourth step is to make the study group population of images available through a web-accessible archive. Such a resource would be a valuable contribution to the field. To accompany the photographs, a set of annotated images can provide a reference for technical analysis and guide for detection and interpretation of errors and other attributes. Such a project could help to advance research in the field, and demonstrate the value of the material to institutions and the general public.

Fifth, as discussed above, the imaging method developed for this project can also be applied to document silk fibre characteristics in intact textiles. Computer vision tools can be devised to measure a statistically significant number of samples as a non-interventional tool for fibre assessment. Textile characteristics derived from computer vision methods can also provide parameters for engineering studies of loom attributes such as warp capacity, dimensions, and lifting weight. We may never know the exact form of some drawlooms in history, but we may be able to understand certain performance characteristics based on data analyses of surviving material.

Sixth, the research presented in this work provides a basis for comparison with other categories of middle Byzantine products produced in professional workshops. Among durable materials, pottery findings may coincide with textile trade patterns. The ceramics picture from the period is one of overlapping networks of regional production with exchange of fine and coarse products.[10] Pottery remains show qualitative distinctions and are graded into various categories. Certain parallels may have existed between imitative production of certain types of ceramics and figured silks that contributed to expansion of technology and development of new production methods.[11]

8.6 Strategic Priorities

While detailed technical analysis coupled with evidence from textual sources represents several research opportunities, scientific dating of fragments is essential to establish technical progression and to integrate art historical methods. Ideally, data gathered from intensive non-interventional studies can be combined with dye analyses and radiocarbon dating for comprehensive characterisation and more informed attribution. The cost and loss of material for destructive testing means that a strategic approach is necessary to maximise the benefit of the resulting information. Without a coordinated, cross-institutional effort, individual museums are unlikely to devote scarce resources to research activities that do not directly support exhibitions. Consequently, progress in the field will depend upon development and implementation of a strategic research programme with the aim of demonstrating the value of historic textile research to historians, institutions, and broader society.

Realisation of such a project requires three fundamental components. First, the support of a well-known research organisation is necessary to demonstrate the potential for cross-functional contributions to scholarship. Second, incremental financial support will be required to fund an integrated programme. In broad terms, the relevance of silk textiles to history and society from technical, social, and economic points of view is well established with scope for sponsorship by various organisations. A requirement will be to define the project in a way that

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[10] Brubaker and Haldon 2011, 496-500; McCormick 2001, 53-63.
[11] For example, see Maguire 1997b; François and Spieser 2002, 603; Vroom 2005, 110-111.

coincides with the strategic interests of private companies, foundations, and cultural institutions.

The textile industry has undergone enormous changes since cultural institutions in Europe and North America were launched in the late 1800s to support commercial and social interests. Silk producers in China, Brazil, India, Thailand, Turkey, and elsewhere have a potential vested interest in linking their industrial progress to developments associated with silk. The historical literature concerning drawloom pattern tie-ups has not been adequately researched to demonstrate the technology as a direct forerunner of computer software, long before development of later loom types such as the jacquard.[12] For cultural funding organisations, the material culture heritage of silk offers abundant opportunities for cross-cultural integration and shared historical developments.

A third requirement is to develop a programme for inter-institutional participation in a manner that coincides with existing programme priorities. This includes definition of opportunities to integrate various constituencies for participation. Use of non-invasive collections documentation can provide the basis for strategic selection of materials for physical testing to extend the benefit of research investment. Sharing this information among institutions can provide a more accurate chronology of technical developments to demonstrate the value of silk textiles to material culture research.

As this work has demonstrated, silk can no longer be considered to be a material of limited importance in the middle Byzantine period and relegated to the margins of scholarship. The evidence presented here provides a firm basis for discarding the ‘Byzantine silk narrative’ in favour of a more expansive perspective that recognises the material in its historical context.

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[12] For an overview of drawloom and advanced loom Broudy 1979, 130-137.

The production and consumption of silk involved a long-term process of adoption, adaptation, innovation, and exchange that occurred within Byzantine society and the region at large.

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Appendix 1.1
Representations of Imperial Dress

Fig. 1 – Lunette panel of Christ and emperor, ca. 900, above central door, inner narthex of Hagia Sophia, Constantinople. Image from: Cormack 2000, 122, pl. 69.

Fig. 2 – Ivory plaque with Coronation of Constantine VII Porphyrogenitos, ca. 945, Constantinople. Moscow, State Pushkin Museum of Fine Arts. Image from: Cormack 2000, 134, pl. 73.

Appendix 1.1

Representations of Imperial Dress

Fig. 3 – Basil II Triumphs over his enemies, wearing *sagion*. Psalter of Basil II, Constantinople, 976-1025. Venice*, Biblioteca Marciana, Ms. Gr. Z* 17, fol. IIIr. Image from: MMA 1997, 186.

Fig. 4 – Nikephoros Botaneiates and his courtiers, ca. 1071-1081. Paris, *BNF, Ms Coilin* 79, fol. 2r. Image from Ball 2005, pl. 3.

Appendix 1.1

Representations of Imperial Dress

Fig. 5 – Alexios I Komnenos (1081-1118) turning to face the chorus of Church Fathers wearing a patterned chlamys. *Vat. Gr.* 666, f. 2r (after 1109-1111). Image from: Parani 2003, pl. 12.

Fig. 6 – Icon with Saint Demetrios dressed in a patterned chlamys, first half of 11th century, Staatliche Museen zu Berlin Kunstgewerbemuseum, Berlin. Image from: MMA 1997, 161, pl. 107.

Appendix 1.2

Textile Glossary

Term	Definition
Beater	Part of a loom; the swinging frame in which the reed is fastened and which also serves to beat in the weft.
Beating In	The beating of the weft as weaving proceeds in order to keep the picks even and the textile compact. This may be done with the reed carried by the beater, with a sword or comb beater or other simple tool.
Binding Harness	The set of shafts that control the binding warp.
Binding Point	Point at which a weft yarn is fixed in place by a warp.
Binding to Pattern Warp Ratio	Describes the ratio of binding to pattern warps
Binding Warp	Binding warps – Yarns manipulated by binding shafts to bind weft floats, resulting in a regular pattern of binding points in the textile. Binding and pattern warps are manipulated independently. Binding warp yarns are threaded through binding shafts and do not enter the pattern harness; pattern warps are entered in the pattern harness and do not pass through the binding shafts.
Comber repeat	A straight repeat in a woven pattern.
Comber Unit	In a drawloom, the section of the comber board, necking cords and leashes that controls one pattern unit in the width of a figured textile.
Cover Factor	Cover factor for woven fabrics indicates the extent to which the area of a fabric is covered by one set of threads. By using numerical constants, its evaluation can be made in accordance with any system of counting. For any fabric, there are two cover factors: warp cover factor and weft cover factor.
Decoupure, pattern steps	The smallest gradation of a design; the smallest number of warp ends (warp decoupure) or the smallest number of picks or passes (weft decoupure) that form one step in the outlines of a design. The weft decoupure is counted by picks if the weft is a single thread, and by passes if more than one weft is used or if the weft is divided into two or more series. It is possible for two decoupures, composed of different number of ends, picks or passes to be used in regular alternation.
Draw-in	The reduction of width of the warp setting during weaving.
Fabric Weight	An estimated value is based on the number of warp ends and weft lats per unit length combined with linear density for each of the yarns in the textile. This value is expressed in terms of grams per square metre.

Appendix 1.2

Textile Glossary

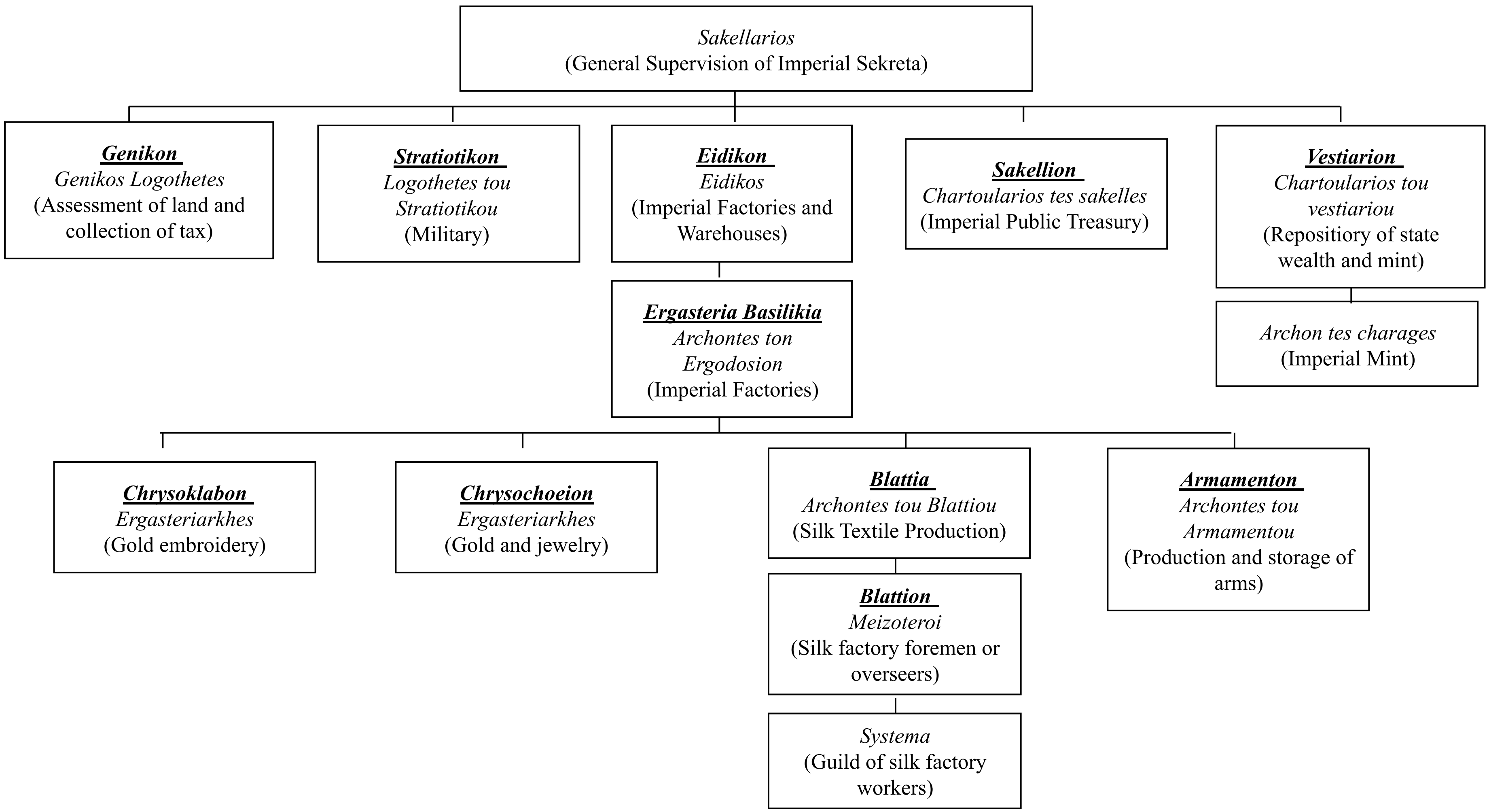
Lat	One of the picks participating in the pass.
Lats per pass	For every weft visible on the surface of the textile, at least one corresponding weft appears on the reverse side of the textile. Patterning is achieved by manipulating pattern warps so that inserted wefts either appear on the face or are pushed below the surface weft. To achieve a patterned effect, at least two wefts must be inserted for each change of the binding shafts. Each inserted weft is called a lat. Each set of lats is called a pass, which are – for the purposes of this measurement - synonymous – with surface weft. In a polychrome textile, there may be up to 5 lats in a pass.
Pass, Weft pass	Yarns oriented in a horizontal direction that appear on the face of a textile. Synonymous with surface weft. One complete cycle of lats that suffices by varied interlacements with the warp to produce the weave and pattern in the full width of a textile. It is constantly repeated in the weaving.
Pattern unit	A pattern unit is composed of one or more motifs, which comprises the smallest divisible portion of the textile design. By repeating this unit, the overall patterning effect of the textile is accomplished. Pattern units are always rectangular in shape in conformance with the grid-based intersection of warp and weft in the process of weaving.
Pattern Warp	Yarns oriented in the longitudinal direction that are manipulated by the figure harness to create the pattern on the textile. For the most part, pattern warps are covered by surface wefts and are not regularly visible except in areas where the weft is worn or distorted.
Pick	A single passage of the shuttle through the shed, carrying one or more weft threads.
Selvedge	The longitudinal edge of a textile, often distinguished by warp ends differing from those in the body of the textile and sometimes by a change in the binding from the rest of the fabric.
Sett	The number of warp ends per centimetre as a measure of density.
Twist	Twist of yarn around its axis resulting from spinning, twisting, throwing or plying. The direction of twist is indicated by the letters S (left twist) or Z (right twist). The tightness of the twist is indicated by the number of turns in a unit of length. Surface helix angle also provides a measure of twist.
Warp	The longitudinal threads of a textile.
Weave	Refers to the method of interlacement to provide the foundation for the

Appendix 1.2
Textile Glossary

Structure (Binding)	weave.
Weave Structure Ratio	Weave structure can be expressed as a numerical ratio, such as 2/2 or 1/3. The first number indicates the number of picks over which an end passes, the second number indicates the number of picks under which it passes.
Weave Unit (Binding)	The smallest cycle of interlacement of warp and weft that is repeated in the binding system.
Weft	The transverse threads of a textile.

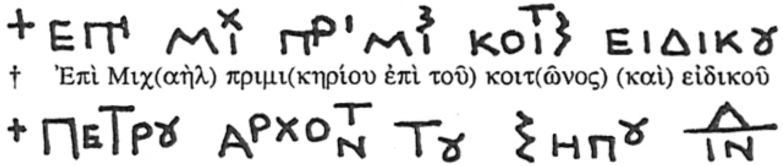
Source: CIETA 2006.

Appendix 2.1
Ninth to Tenth Century Palatine Administrative Structure for the Imperial Silk Workshops



Appendix 2.2

Inscription from the ‘Imperial Elephant’ Silk



† Ἐπὶ Μιχ(αὴλ) πριμι(κηρίου ἐπὶ τοῦ) κοιτ(ῶνος) (καὶ) εἰδικοῦ

† Πέτρου ἄρχοντ(ος) τοῦ Ζευξήπου ἰνδ(ικτιῶνος) [...]

In the time of Michael, πριμικήριος ἐπὶ τοῦ κοιτῶνος and εἰδικός
When Peter was the archon of Zeuxoppos, indiction [...].

Source: Translation by Muthesius 1995f, 64-65, pl. 47A. Note that transliteration of Zeuxoppos should be Zeuxepou.

Appendix 2.3

Seals of the *Archontes tou Blattiou*

40. Ambros, imperial silentiarios, archon of the blattion, and general (kommerkiarios) (776-780)

Dumbarton Oaks Collection 55.1.4391. D. 28 mm.
Ed.: Zacos-Veglery, no. 272. Cf. Likhačev, *Datirovannye*, 204, pl. IX/6.

Obv. Two emperors, Leo IV (left) and Constantine VI (beardless), dressed with chlamydes and seated on thrones. No border visible.

Rev. Divided by a horizontal line. In the upper half, busts of two (deceased) emperors wearing the loros: Leo III and Constantine V. In the lower half, inscription of four lines. No border visible.

.ṂBPⲰBꞩCIΛ.Ṇ|..AP´SAPXONT.|..BΛΛ´SΓЄN||..Ḳ...

[῎Α]μβρῳ β(ασιλικῷ) σιλ[ε]ν[τι]αρ(ίῳ) (καὶ) ἄρχοντ[ι τοῦ] βλα(ττίου) (καὶ) γενι[κῷ] κ[ομμερκιαρίῳ].

The reconstruction of the last line is based on several parallels, cf. Zacos-Veglery, 204-205. The imagery reproduces faithfully that of coins issued by Leo IV (Grierson, *Catalogue* III/1, pl. 12, esp. class 2), and consequently the attribution and date of this seal are secure, the more so since it represents two emperors who are alive and two who are dead.

42. Anthimos, hypatos, imperial asecretis, general kommerkiarios, and archon of the blattion (780-797)

Fogg Museum of Art, no. 1744. D. 33 mm.
Ed.: Zacos-Veglery, no. 275; Laurent, *Corpus* II, no. 658.

Obv. Two busts: Constantine VI (left) is beardless and wears crown and chlamys; his mother Eirene wears the loros and the empress' crown with pendilia and triangular projections on the top. No border visible.

Rev. In the upper half, busts of three bearded emperors wearing chlamydes: Constantine V, Leo III, and Leo IV. Below, inscription of four lines.

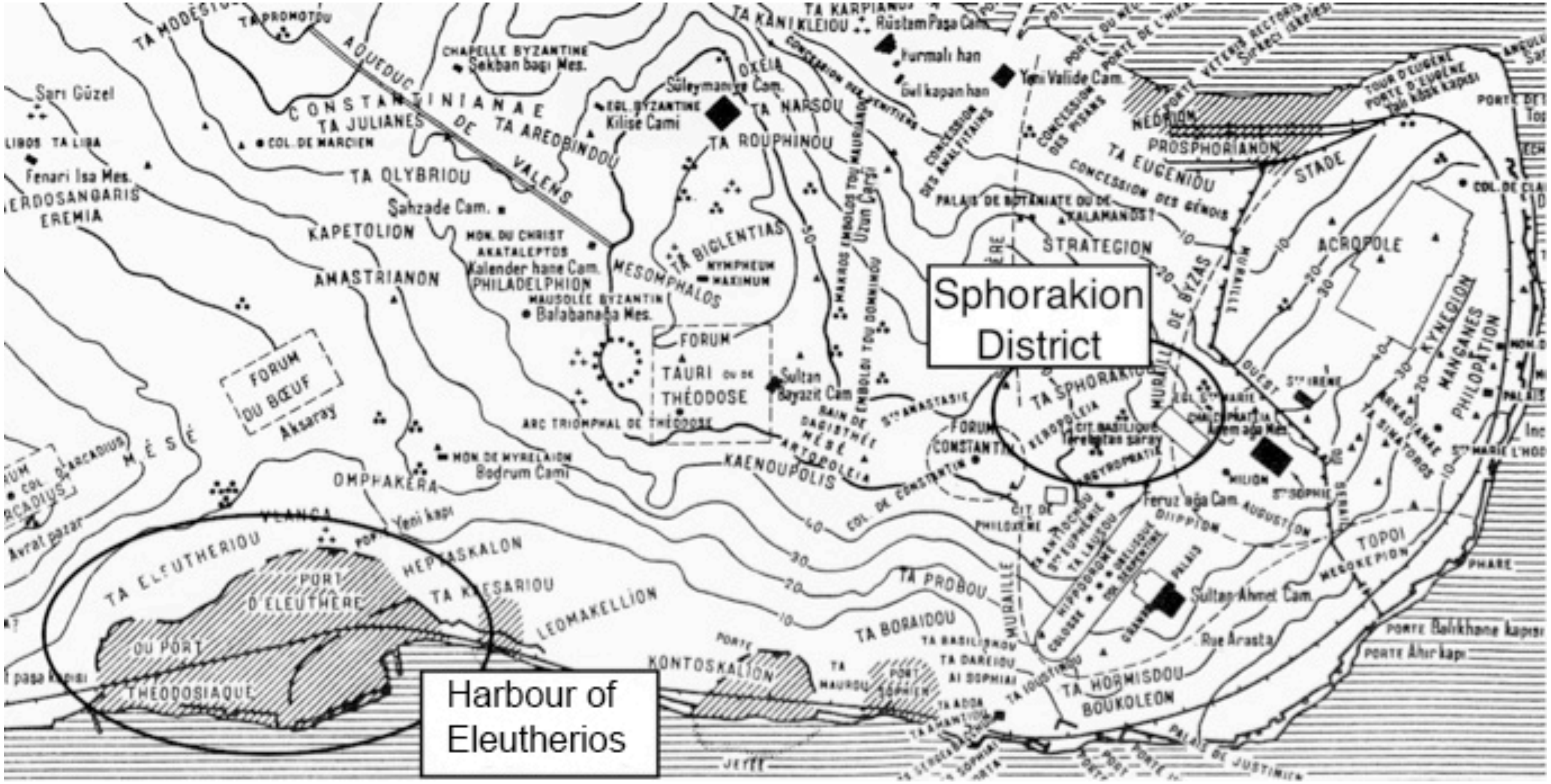
.ṆΘIMⲰVΠ´B`AÇ|..PꞩΓЄNIKꞩKOṂ|.ẸPKꞩSAPXꞩT|..A....

[᾿Α]νθίμῳ ὑπ(άτῳ), β(ασιλικῷ) ἀσ[ηκ]ρ(ῆτις), γενικ(ῷ) κομ[μ]ερκ(ιαρίῳ) (καὶ) ἄρχ(οντι) τ(οῦ) [βλ]α[ττίου].

The editors read on the reverse the Greek letter Θ for indiction 9, which would date the seal to the year 785/86; but I do not see that letter and for this reason propose a broader dating. The identification of the emperors is beyond any doubt (three deceased emperors; a living empress, Eirene) and has some numismatic parallels in bronze coins (Grierson, *Catalogue* III/1, pl. 14, classes 5 and 6).

Source: Oikonomides 1985, 50-52.

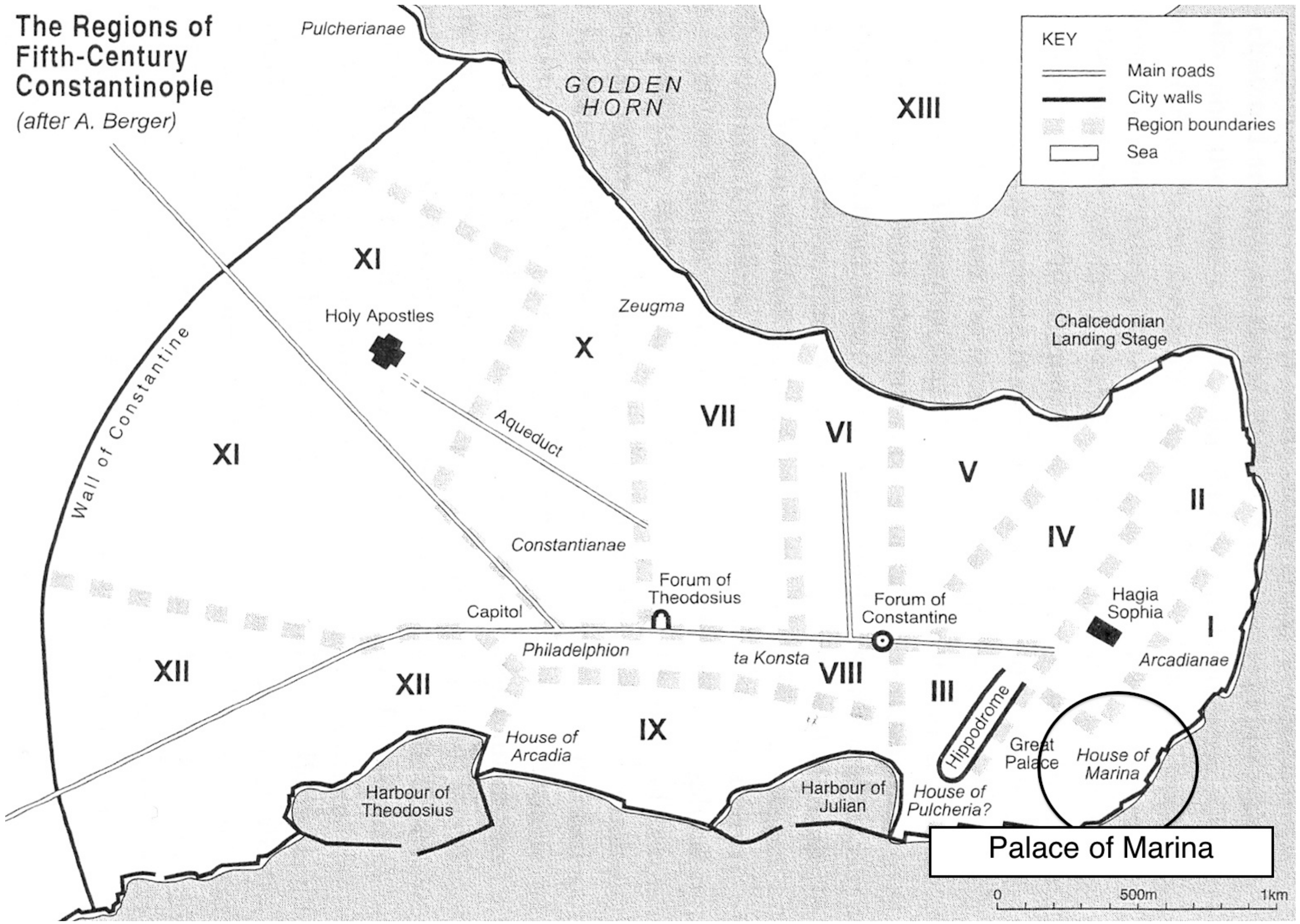
Appendix 2.4
Map of Constantinople



Source: Janin 1950, enclosed map.

Appendix 2.5

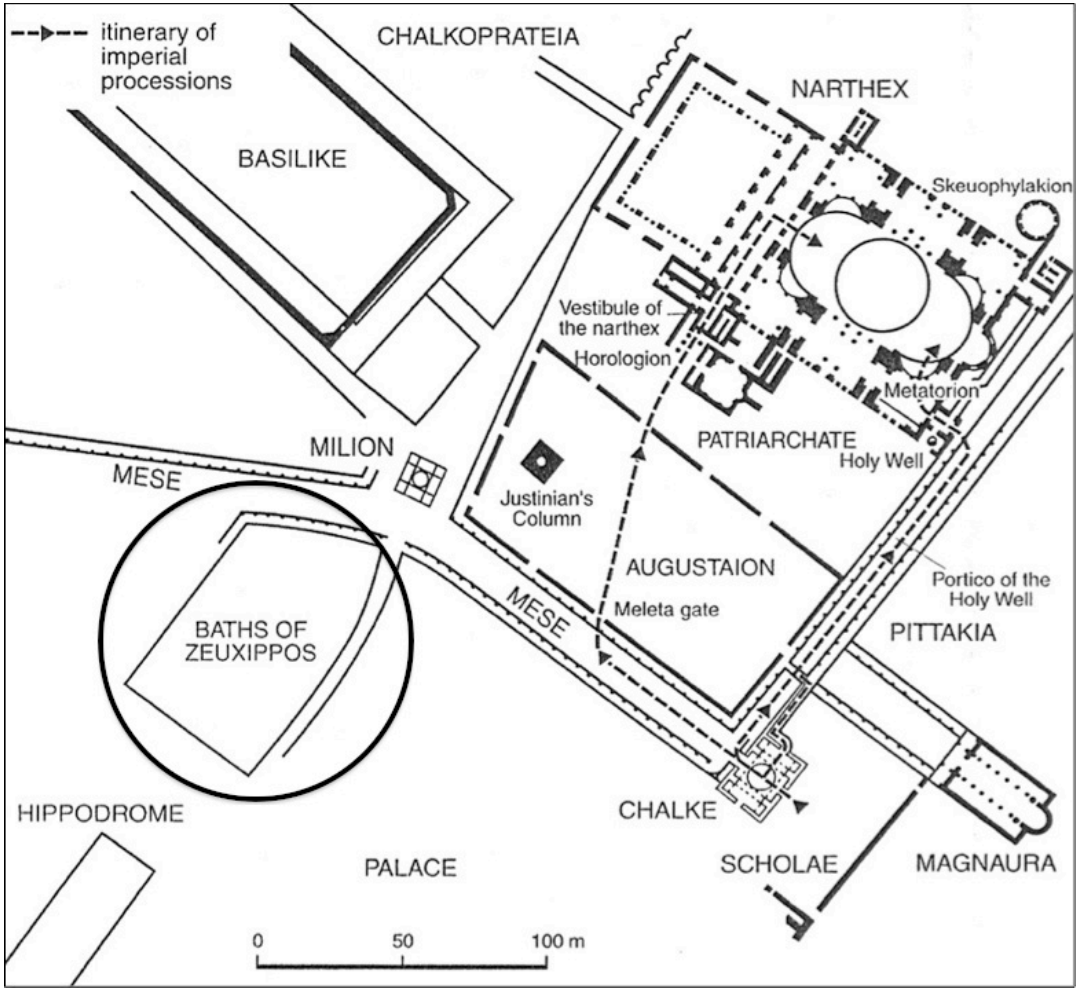
Map of the Fifth-Century Regions of Constantinople



Source: Magdalino 2001, 54.

Attachment 2.6

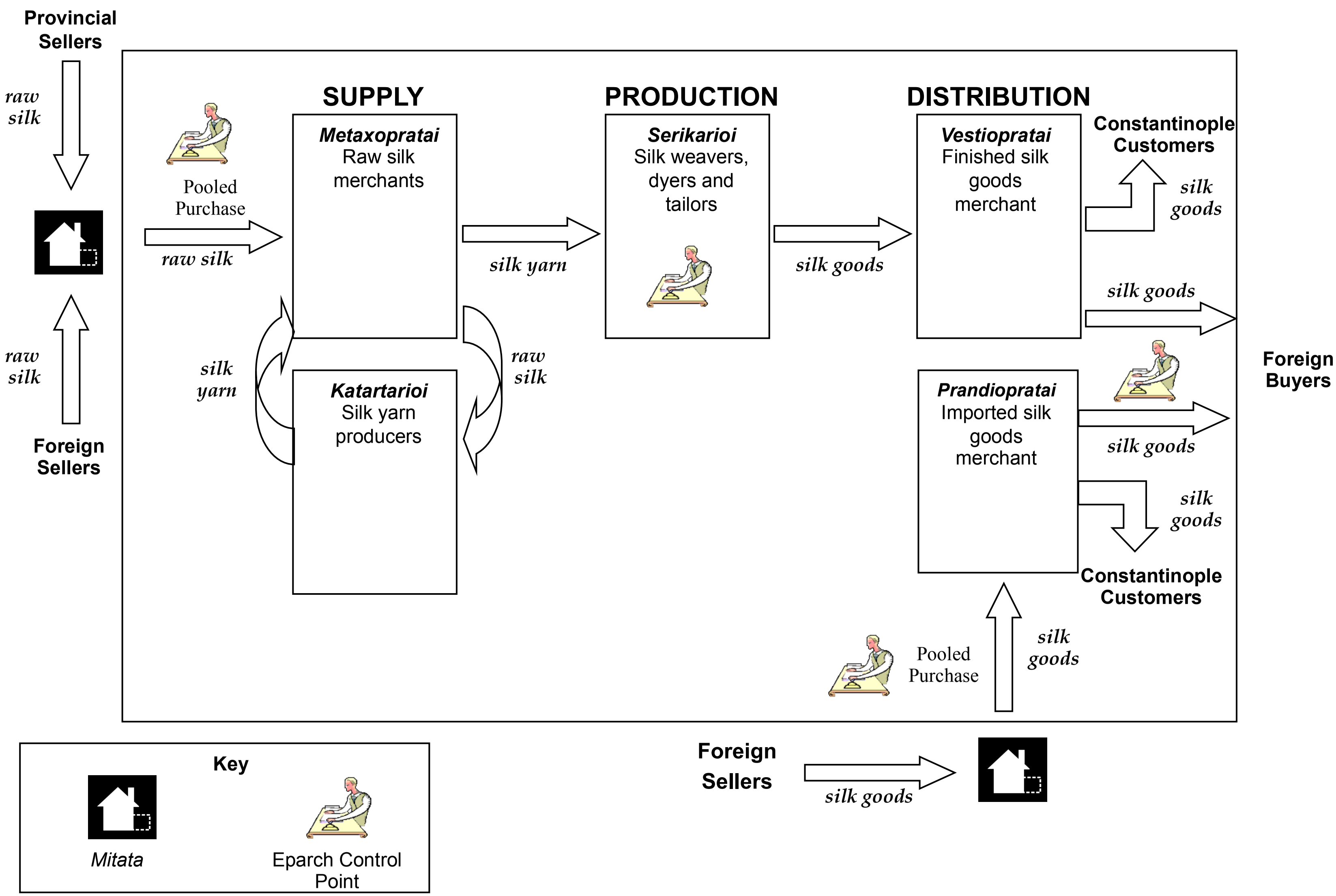
Map of Palace Area



Source: Mango 1959, 23.

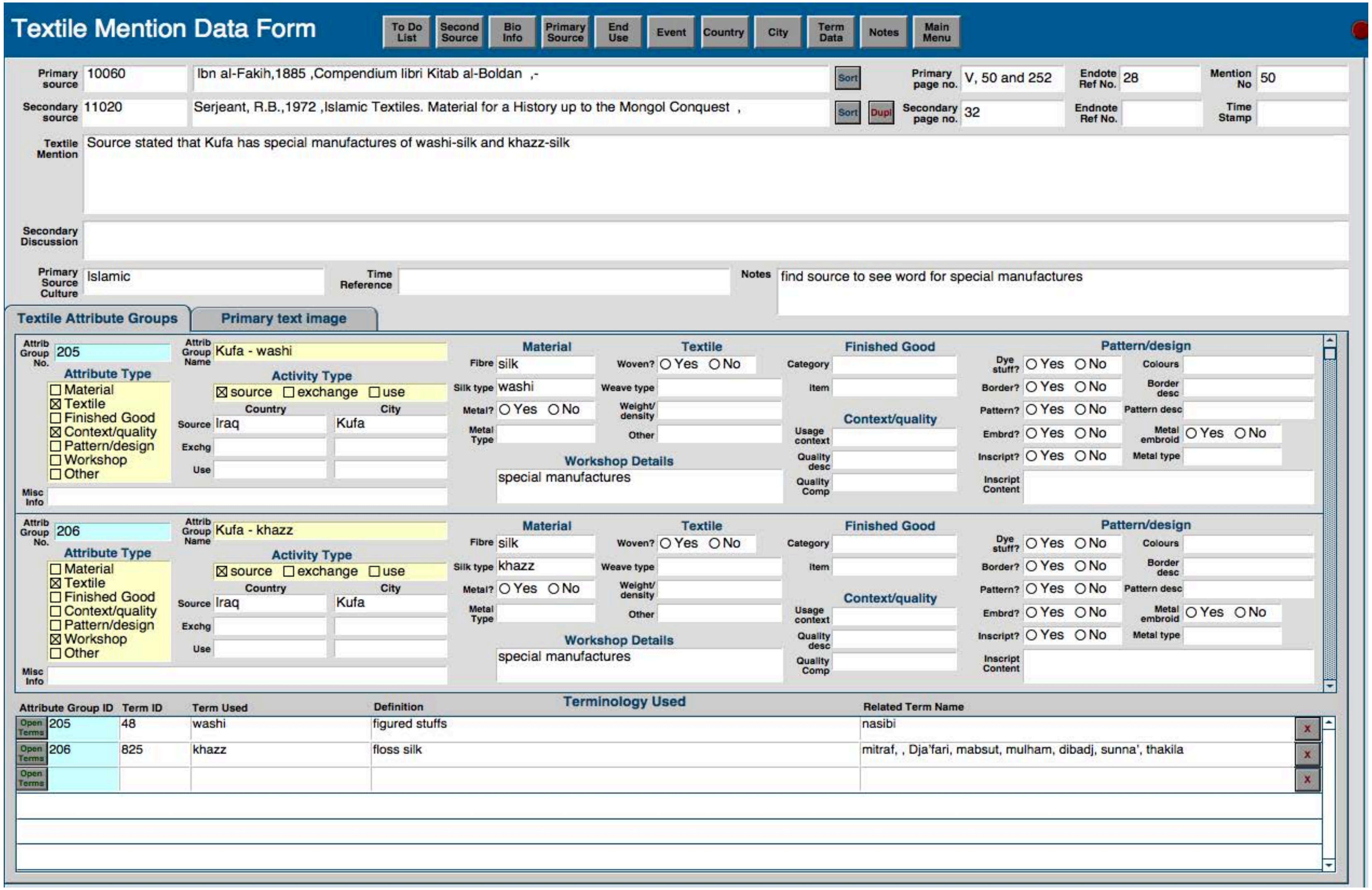
Appendix 2.7

Schematic Overview of Private Silk Production and Distribution System



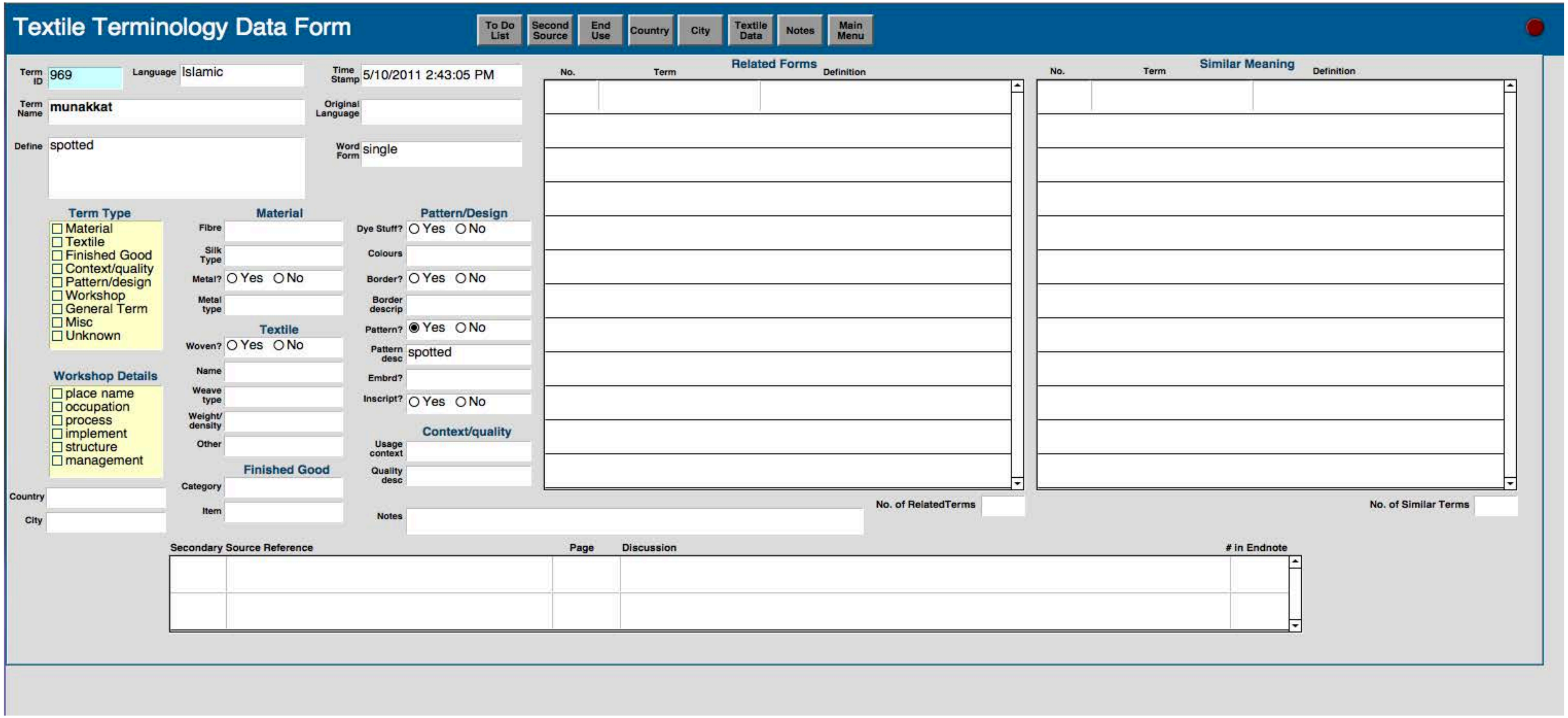
Appendix 3.1

Textile Mention Database Layout



Appendix 3.2

Textile Terminology Layout



Appendix 4.1

Textile Mention Data Summary

Summary by source	Men No.	Blattia	Serica	Metaxa	Other fibres	Other textiles	Textile terms	Metal	Other dec	Purple	Other Colour	Pattern	Quality	Other garments	Geogr	Other	Symbol	Metaph	Key Event	Silk implied Total	Colour	Embell	Descrip	Context	Not silk
Menander	11	0	4	7	0	0	0	0	0	0	0	0	0	0	0	2	0	0	7	0	0	0	0	0	0
Nikephoros	10	0	1	0	0	0	0	0	0	1	1	0	2	0	0	9	9	0	1	5	1	0	4	4	2
Theo Confessor	35	0	2	2	7	3	3	6	3	5	4	3	1	0	0	10	21	2	7	15	6	6	6	8	9
Vita Basilli	19	0	4	0	1	1	5	2	0	0	0	2	3	1	0	9	1	1	8	5	0	2	4	2	3
Leo Deacon	13	0	0	0	0	0	0	3	0	8	2	0	0	1	0	3	5	0	5	9	5	4	5	9	1
Leo Synada	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
Skylitzes	27	0	0	0	3	0	0	5	1	6	1	0	0	0	0	19	16	2	12	14	5	4	0	14	8
Atteliates Historia	21	0	1	0	1	0	0	1	1	2	5	0	6	0	2	10	16	2	2	11	2	1	7	6	6
Psellos	26	0	1	0	2	0	1	2	1	6	2	0	1	0	0	16	20	1	0	13	9	2	1	13	8
Komnene	34	1	5	0	0	0	3	2	2	12	7	0	0	1	0	12	5	1	1	15	9	3	1	12	6
Choniates	85	0	3	0	19	8	31	15	14	19	8	2	11	62	2	12	39	13	21	29	18	15	12	27	2
Sub-total	283	1	21	10	33	12	43	36	22	59	30	7	24	65	4	104	133	22	64	116	55	37	40	95	45
DAI	16	1	0	0	1	1	0	1	1	0	1	0	1	0	1	13	8	0	1	9	1	1	8	8	3
Listes	32	2	0	0	2	1	0	12	2	1	22	0	0	0	0	5	0	0	0	26	13	9	1	26	2
BOC	352	17	4	5	16	12	0	106	31	80	137	47	8	18	6	28	0	0	0	275	134	132	6	274	13
Imp Expeditions	56	16	0	2	5	13	22	9	8	14	12	11	20	3	2	1	0	0	0	22	11	7	18	22	1
Sub-total	456	36	4	7	24	27	22	128	42	95	172	58	29	21	9	47	8	0	1	332	159	149	33	330	19
Kosmas Indikopleustes	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0									
Rhodian Sea Law	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0									
Attleiates Diataxis	19	13	0	0	1	0	12	1	3	4	5	12	0	0	3	4									
Other Inventories*	102	51			8		2	5	1	7	14	14	2			56									
Total	865	101	27	20	66	39	79	170	68	165	221	91	55	86	16	211	141	22	65	448	214	186	73	425	64

*Includes Patmos 50, Lavra 22, Panteleem No. 7, Iviron No. 44 and Iviron No. 47

Appendix 4.2

Varieties of Silk Found in Cairo Genizah Documents

Silk Type Name	Description	Relative cost	Notes	MS Number
Harir	Standard silk			
Ibrasim	Came from Khorasan via Aleppo. But also frm Ahwaz in southwest Iran			TS 13 J 25, f. 18, l. 12
Iltiquat Andalusi	Spanish "pickups" could refer to schappe (spun) silk			Bodl. MS Heb. b 3 (Cat. 2806), f. 19, l 18+
Jizi	Derived from jiz, chrysalis (cf. Dozy, Supplement, I, 234a), designates a top variety extracted from the best part of the silkworm cocoon			TS 12.251, l. 18 (ca. 1030); Bodl. MS Heb. C 28 (Cat. 2876), f. 61, ll. 28-29+
Khazash or Khashaz, or Khazzaj	Inferior quality	When 10 pounds khazz cost 36-39 dinars, khazash cost 10		TS 10 J 10 f. 23, 1. 12, India Book 251; ULC Or 1080 J 258, l. 12
Khazz	Superior quality	When 10 pounds harir cost 22-30 dinars, khazz cost 50 dinars	1 pound of khazz cost 3.25 dinars "and would have been higher had not the Syro-Palestinian silk arrived."	TS 13 J 27, f. 4, ll. 27-30; TS 13 J 19, f. 27, l. 8+
Ladh	Red silk, originally produced in China, later imitated in Sicily			
Lanas or lenas	India red silk, a major item in the India trade, was strangely			TS 12.147

Appendix 4.2

Varieties of Silk Found in Cairo Genizah Documents

Silk Type Name	Description	Relative cost	Notes	MS Number
	absent from Mediterranean			
Lasin	Inferior quality, coming mainly from Sicily, but also Iraq	Cost 1 dinar/pound when standard silk was as high as 2 2/3 dinars a pound		ULC Or 1080 J 119
Manqud	Unravelled silk			
Maqshur or Manqashshar	Peeled off silk			
Qatarish	Tangled waste silk, (catarzo – modern Italian word for floss silk appears in 11th century business letter in the form of qatarish)		According to suggestion by R.S. Lopez, derived from Greek katartarioi, silk spinners	
Qazz	Black and red, perhaps used more in Palestine and Egypt			
Siqli	Sicilian silk			
Susa	Tunisian silk?			
Zaytuni mujalla	Glossy zaytuni, term derives from Zaytun or Chuanchow in China, it does not occur in Geniza docs dealing with India trade, see Dozy Supplement, I, 617a.	In 1048 cost about 1 dinar/pound	700 pounds of zaytuni seem to come from the West	TS 20.69v, l. 20; TS 13 J 8, f. 13, sec. B, L 2, Nahray

Source: Goitein 1967-1993, I n. 53, 454; Gil 2002; Serjeant 1972, 89.

Appendix 4.3

Byzantine Terms in the *BOC* for Gold Woven or Applied to Textiles

Transliteration	Greek	Definition	Incidence
chrysokentetos	χρυσοκέντητος	Embroidered with gold, from Greek κεντέω meaning to stab or prick	3
chrysosolenokentetos	χρυσοσωληνοκέντητος	Refers to thin tubes of gold, based on the word *solen* (σωλήν) to mean pipe or channel.	1
Chrysoyphantos chrysoyphes	χρυσοῦφαντος χρυσοϋφής	Woven with gold, based on ὑφαντός Woven with gold, based on ὑφή with the meaning of web	14
chrysosementos	Χρυσοσήμεντος χρυσά ὁλοσήμεντα	Gold patterned from the Latin segmentum	1
chrysoklabos	χρυσόκλαβος	Bands of gold	10
chrysotablion	χρυσοτάβλιον	Tablion of gold	12
chrysoperikleistos	χρυσοπερίκλειστος	Gold bordered, might have been tablet woven braids. Only applied to a particular class of garment: sagion, capes correspondence and technical precision.	27

Source: *BOC*; Dawson 2002, 26-30.

Appendix 5.1

Terms Used to Describe Weft-Faced Compound Weave Textiles

Term	**Source**
levantine or “three end satin	Stephani 1881, 141
figured-wool weave	Flanagan 1919, 168
draw-loom weaves in wool	Kendrick 1921, 265
ingrain material	Stein 1921, 265
drawloom weavings	Wilson 1933, 13
compound cloth weaving	Ashton 1935, 29
compound twill (both forms)	Reath and Sachs 1037, 56
rep and twill polymita	Lamm 1937, 12
two-faced weave with pattern in reverse	Crowfoot and Griffiths 1939, 40
drawloom weavings	Lamm and Charleston 1939, 13
compound weft rep	Sylwan 1949, 35
woollen damasks	Watson 1973, 130
compound structure, a weft-faced twill with inner warps and complementary wefts	Harper 1978, 132
Coptic double weaves	Crowfoot (in Plumley 1977, 46)
weft-faced plain weave, complementary wefts and inner warps	Mayer-Thurman and Williams, 1979, 97
compound tabby weave	King 1981, 5
drawloom textiles	Trilling 1982, 96

Source: Vogelsang-Eastwood 1988, 8.

Appendix 5.2

CIETA DOSSIER

I	Present locality: (Owner)	Museum - Collection – Church Inventory number
II	Attribution:	Place of manufacture Date of manufacture
III	Provenance:	Place and date of discovery or donor or seller Date of entry into the Collection
IV	Type of textile:	Costume, vestment, fragment
V	General measurements:	Greatest height and width of textile Height and width of design repeat Additional measurements, e.g. diameter of roundel, width of individual motif
VI	Condition:	
VII	Description:	Design, colours, applied elements of decoration, e.g. embroideries, etc.
VIII	Technical description:	A. Type of weave: Warp: proportion: material, twist, colour: pattern step (decoupure): thread count: Weft: proportion: material, twist, colour: pattern step (decoupure): thread count: B. Inner structure: (It is desirable to have a diagram)
IX	Dyeing and/or treatment: chemical analysis, if known	
X	Method of production:	
XI	Commentary justifying attribution:	
XII	Commentary justifying the condition of execution:	
XIII	Other pieces of the same textile, and similar pieces:	
XIV	Bibliography concerning this specific textile:	
XV	Date of analysis and signature of analyst:	

Source: CIETA 1957.

Appendix 5.3

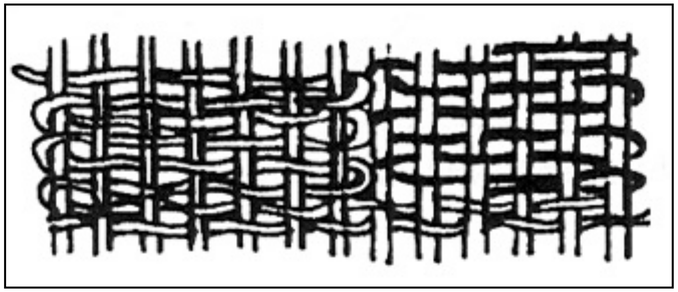
Attribution Summary – Period I Silks (Up to Eighth or Ninth Centuries)

Category	Date	Description and orientation	Structure
1. Wool taqueté	3-5th	bi-colour hunting scenes with the design woven parallel to the warp	1/1 taqueté, alternating weft insertion, 1:1 binding to main warp ratio, S twist warps, 2 lats per pass
2. Christian-theme silks	4-6th	bi-colour woven with very fine yarns	1/2 samite S twill, alternating weft insertion, 1: 1 binding to main warp ratio, Z twist warps, 2 lats per pass
3. 'Antinoe' silks	5-7th	polychrome silks woven parallel to the warp with long, narrow pattern repeat	1/2 samite S or Z twill, alternating weft insertion, 1:1 binding to main warp ratio, Z twist warps, usually more than two lats per pass
4. Small pattern motif silks	various	bi-colour silks woven with short geometrical pattern repeats	1/2 samite S or Z twill, alternating weft insertion, 1:1 binding to main warp ratio, Z twist warps, 2 lats per pass, some have a third colour inserted on an interrupted basis in visible bands
5. 'Akhmim' silks (three sub-groups)	7-9th	bi-colour silks woven with pattern perpendicular to the warp, three sub-groups	1/2 samite S or Z twill, returning weft insertion, 1:1 binding to main warp ratio, Z twist warps, 2 lats per pass, Z twist warps
6. 'Alexandria' silks – red group	8-9th	polychrome silks with red warps, pattern perpendicular to warps	1/2 samite S twill, returning weft insertion, 1:2 binding to main warp ratio, Z twist warps, 4 or more lats per pass
7. 'Alexandria' silks – blue group	8-9th	polychrome silks with blue warps, pattern perpendicular to warps	1/2 samite S twill, returning weft insertion, 1:2 binding to main warp ratio, Z twist warps, 4 or more lats per pass
8. Eastern samites (two subgroups)	6-9th	polychrome silks, pattern perpendicular to warps, two sub-groups	1/2 samite S twill, returning weft insertion, 1:2 binding to mainwarp ratio, untwisted warps, 3 or more lats per pass, two sub-groups

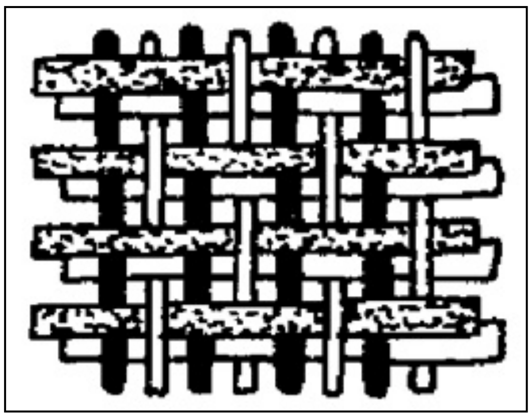
Source: Desrosiers 2004, 14-18.

Appendix 6.1

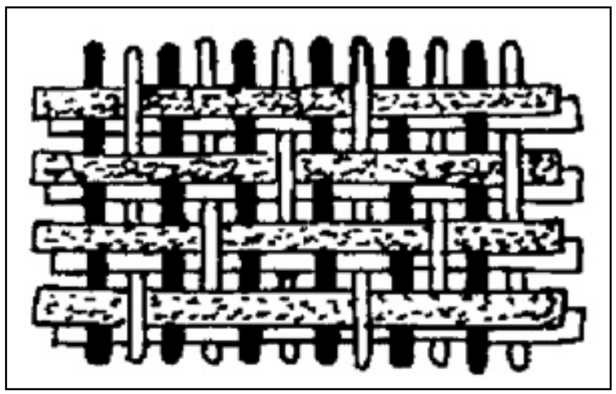
Weave Structure Overview



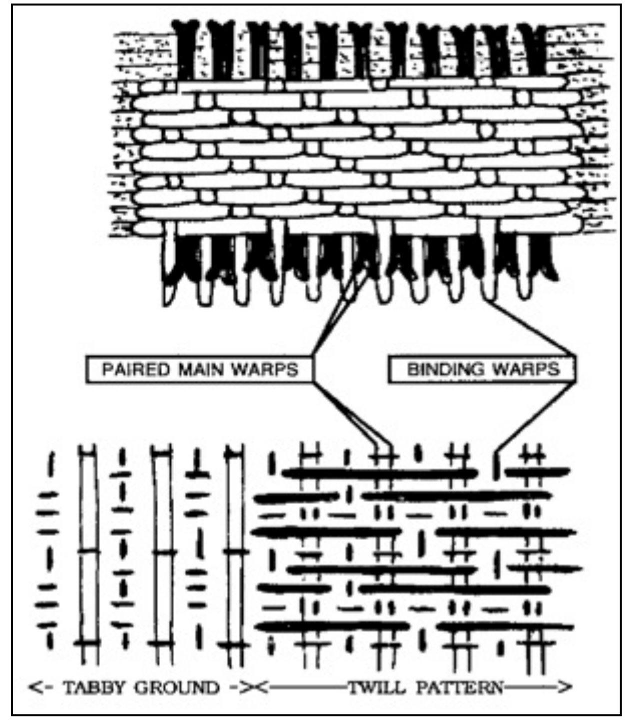
Tapestry Weave



Taqueté (Weft-faced Compound Plain weave)



Samite with Single Main Warp (Weft-faced Compound Twill)



Samite with Paired Main Warps (Weft-faced Compound Twill)

Sources: Muthesius, 1995, p. Plate 1.

Appendix 6.2

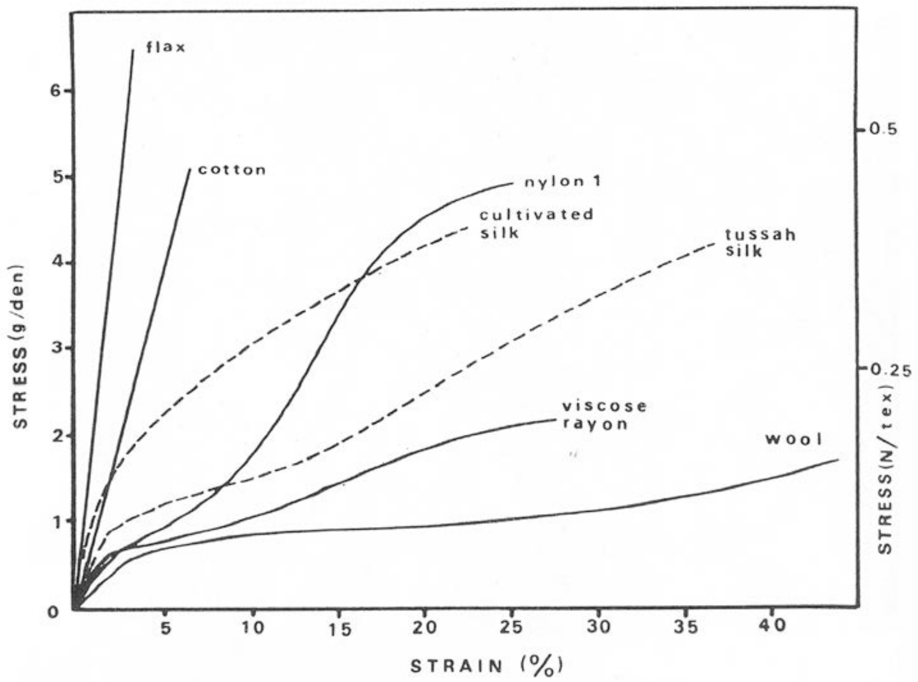
Tensile Properties of Silk

Fiber[a]	Tenacity (N/tex)	Breaking extension (%)	Work to rupture (mN/tex)	Initial modulus (N/tex)	Yield stress (mN/tex)	Yield strain (%)
Cotton—St. Vincent	0.45	6.8	14.9	7.3	—	—
Flax	0.54	3.0	8.0	18.0	—	—
Viscose rayon—continuous filament	0.18	27.2	30.6	4.8	57	2.0
Silk—cultivated	0.38	23.4	59.7	7.3	156	3.3
Nylon	0.47	26.0	76.0	2.6	407	16.0
Wool—Botany 64s	0.11	42.5	30.9	2.3	57	5.0

[a]1-cm test length; 65% rh; 20°C; rate of loading 0.9 N/tex^{-1} m^{-1}.
Source: Refs. 132 and 140.

Source: Lewin, M. and Pearce, E.M. (1998), 447.

Stress-Strain Curves

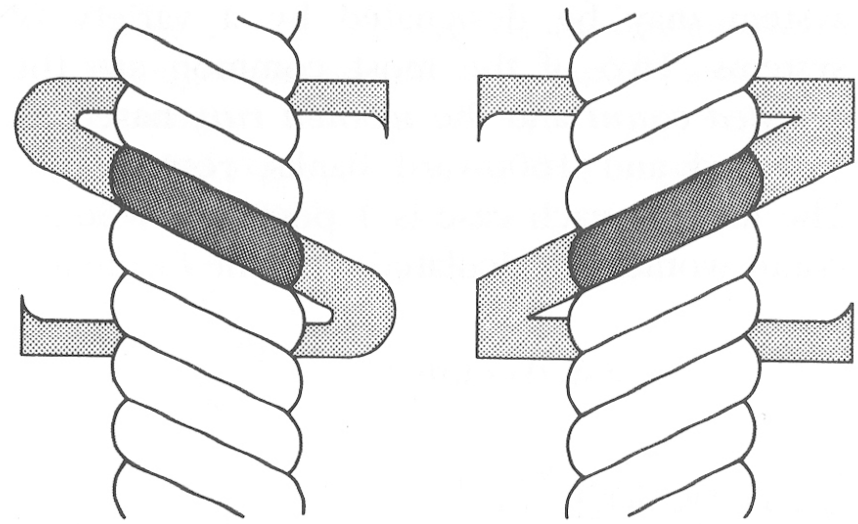


Typical stress-strain curves for silks and other fibers. Constant rate of loading of 10 g f den^{-1} min^{-1} (0.9 N/tex^{-1} min^{-1}) at 65% rh, 20°C. (From Ref. 132.)

Source: Lewin, M. and Pearce, E.M. (1998), 446.

Appendix 6.3

Diagram of S and Z twist direction in yarns



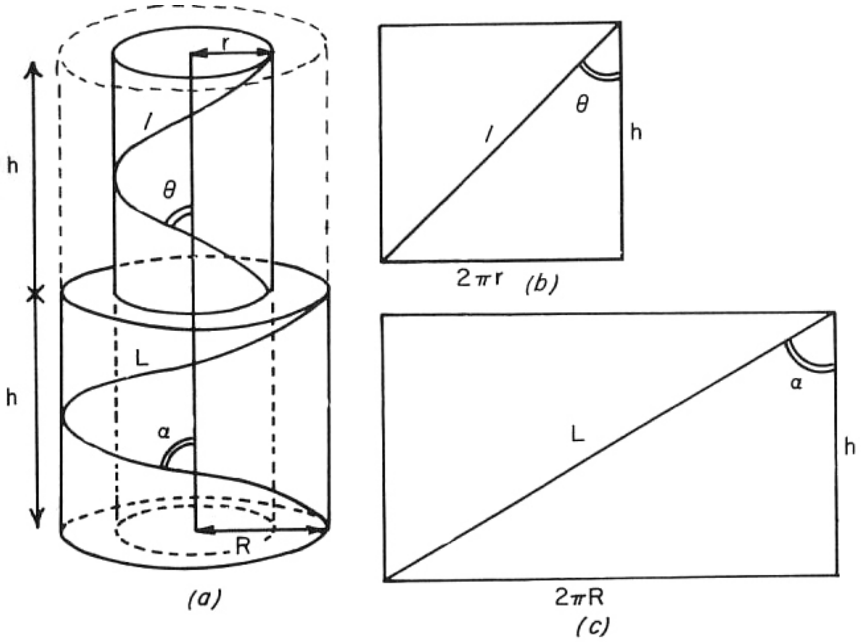
Source: Hudson, Clapp, et al. 1993, 160.

Appendix 6.4

Computer Vision Test Specifications

Test Name	Mag (x)	Computer Vision Method	Characteristics			Errors	
			Material	Textile	Pattern	Tie-up	Weaving
Yarn diameter	150x	Template matching	X				
Surface helix angle	150x	Shape detection	X				
Fragment dimensions	1x	Measurement		X			
Fragment width in warps	50x	Template matching		X			
Fragment length in wefts	50x	Template matching		X			
Cover factor and weight	-	Calculated value		X			
Pattern unit dimensions	1x	Measurement			X		
Pattern unit width in warps	50x	Template matching			X		
Pattern unit length in wefts	50x	Template matching			X		
Calculated intersection points	-	Calculated value			X		
Binding points interior distance	50x	Template matching				X	
Pattern unit uniformity	1x	Change detection				X	
Pattern warp tie-up error	1x	Change detection				X	
Pattern warp selection error	1x	Change detection					X
Incorrect binding shed sequence	50x	Template matching					X
Missing binding warp	50x	Template matching					X

Appendix 6.5
Measurement of Surface Helix Angle



Idealized helical yarn geometry. (*a*) Idealized geometry; (*b*) "opened-out" diagram of cylinder at radius *r*; (*c*) "opened-out" yarn surface.

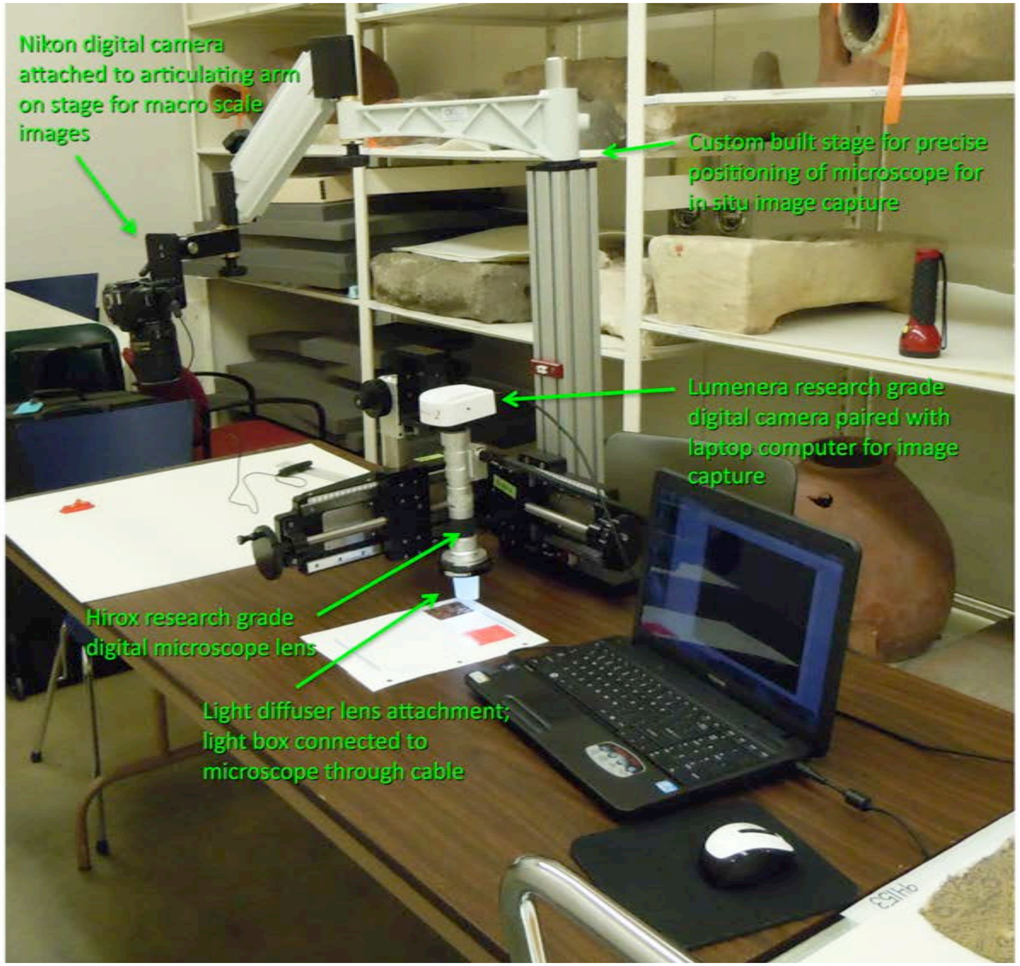
Source: Hearle, Grosberg, et al. 1969, 65.

Appendix 6.6

Initial Research Protocol Equipment Setup

Appendix 6.7

Formal Research Protocol Equipment Setup



Attachment 6.8
Image Capture Protocol

Equipment List for *in situ* image capture:

	Major Equipment	Number
	Hirox CX-MACROZ VI Macro lens with top and bottom lens caps	1
	Hirox CX-5040SZ Zoom lens with top and bottom lens caps	1
	Hirox KMH-24 metal halide lamp with light guide and power supply cable	1
	Diffuser adapter for CX-5040SZ lens	1
	Nikon D3100 digital SLR camera with charger, 16 GB SD card in slot, and USB camera cable	1
	Micro-NIKKOR 105mm f/2.8 lens with cap	1
	Stereomicroscope boom arm adapted to mount Nikon camera	1
	Lumenera Infinity 2.2 Megapixel c-mount camera with USB 2.0 cable	1
	Old School Custom portable x-y microscope stage	1
	Toshiba Satellite C655 15" laptop computer with Windows 7 with Infinity Analyze software for image capture with power supply and portable optical mouse	1
	MacBook Pro 13" with OSX.6.8. with power supply and portable optical mouse	1

	Accessories	Number
	Bull's eye-type liquid balance	1
	Lumenera key fob to enable processing of image stacks	1
	Spare 16 GB SD cards	2
	Test diagrams for micro and macro scale camera positioning	2
	Sample textiles for set up testing	3
	Precise tracking surface mouse pads	2
	Power strip – 110-120 volts	1
	Power strip – 220-240 volts	1
	Extension cords – 110-240	3
	Plug adapters	6
	External hard drive	2
	Spare light bulb for metal halide light	1
	Phillips screw driver to open light housing	1
	Stage micrometer (10 mm/0.1 mm div)	1
	Stage micrometer (1 mm/0.01 mm div)	1
	Precision cm metal ruler with trimmed paper photocopies on card stock	1
	Standard grey scale and colour charts to include with macro view photo of textile for potential future colour adjustment	1 set
	Hard copy A4 size colour print outs of each textile to be photographed	1 set
	Writing pads	1
	Sharp pencils	5
	Voice recorder	1

Attachment 6.8

Image Capture Protocol

	Spare AA batteries for voice recorder and mouse	3
	Cotton gloves - pair	2
	Fine probe with cork tip	1
	Tweezers – bent nose 6" length	1
	Tweezers – pointed – 4.5" length	1

Microscope Equipment Set-up Steps for Image Capture

1. Set-up the Windows computer on the work surface and attach the power cable. Start the Image Analyze application.
2. Place the metal halide lamp housing on the work surface and attach the power supply. Position the adjustable iris lever controlling lamp intensity to the ½ open position.
3. Assemble the microscope x-y stage and secure it to the work surface with the screw-on support.
4. Place the balance on the x-y stage to make sure that the supports are perpendicular to the work surface. Adjust as necessary.
5. Mount the microscope camera on the CX-5040SZ Zoom lens and attach the diffuser.
6. Fasten the lens/camera to the focusing block on the microscope stage.
7. Securely attach the light guide to the lens assembly and turn on the light.
8. Attach the USB camera cable to the Windows computer. Verify that the software recognises the camera.
9. Import the file folders set up during the pre-work phase to contain the image series by scale for each textile to be photographed.
10. Perform a white balance in Infinity Analyze to adjust the sensor to light conditions.
11. Enter the following settings into the camera software: Auto exposure box checked, average pixel brightness = 135, camera gain = 9.64, screen gamma 1.0. Images should be saved in tiff format.
12. Select the 50x magnification level on the lens and take a test photo of the microscope test diagram. Make sure that the measurement scale is recorded on the image. Verify that the time and date recorded with the image are correct. Compare the test image with the control image in the reticule file. Adjust the lens position if necessary and repeat this step until the assembly is appropriately positioned in terms of the work surface.
13. Position the test textile under the microscope lens. Adjust the coarse and fine focus knobs until the image is sharply focused and take test photos. Compare the test images visually with the control test textile images in the reticule file. Adjust the equipment and software settings as necessary and repeat the steps above until satisfactory images are obtained.

Attachment 6.8

Image Capture Protocol

Macro scale Equipment Set-up Steps for Image Capture

1. Set-up the Mac computer on the work surface and attach the power cable. Start the Image Analyze application in the virtual Windows environment.
2. Assemble the camera mount (articulating arm camera stand) and secure it to the work surface with the screw-on support.
3. Position the camera on the stand. Use the balance to verify perpendicular positioning. Adjust as necessary.
4. Connect the camera to the computer with the USB camera cable.
5. In the camera software, load the file names previously created during the pre-work phase.
6. Perform a white balance to adjust the sensor to ambient light conditions. Verify that date and time settings are accurate. Enter the following settings into the camera software: Auto focus, auto exposure, image format: tiff. Select the: never turn off setting.
7. Take a test photo of the camera-positioning diagram. Transfer the image to the Infinity Analyze application on the laptop and verify correct camera position. Repeat this step until the camera is appropriately positioned in terms of the work surface.
8. Position the test textile under the macro scale camera lens. Place the paper cm ruler in the field of view. Adjust the light settings and focus the lens. Take test photos. Compare the test images visually with the control test textile images in the reticule file. Adjust the equipment and camera settings as necessary and repeat the steps above until image quality is satisfactory.

Macro Scale Documentation and Image Capture Work Steps

1. Open the textile characteristics database on the Mac computer and select the first textile to be photographed and analysed.
2. Inspect the textile in its mount and make observations. Compare the textile with database entries obtained from published sources. Note any discrepancies.
3. Use the voice recorder to document observations and notes.
4. Using the hard copy A4 colour photograph, sketch in areas too degraded to include in data collection. Also indicate areas where the surface is uneven and image stacking will be required to obtain an in-focus view under the microscope camera. Note areas of interest on diagram for additional macro and micro scale photographs.
5. Position the textile under the camera. The first image should be focused on the label or other identifying information affixed to or accompanying the textile.
6. Position the textile for a second photograph. Place the following items in the field of view: paper ruler, grey card and colour reference card. Take a photograph.
7. Take additional macro scale photos of the textile, making sure that the ruler is in the field of view for all shots.
8. Position the camera to take a macro view image of each pattern unit. Once the camera mount height is set, do not change the focal distance to ensure

comparability among pattern unit photos. Position the textile underneath the camera if possible.

9. For consistency among shots of pattern units, image capture should always be started in the upper left corner of the textile, with the camera moved to the right, then down and to the left for subsequent photographs.
10. Take additional photos of areas of interest as noted on A4 diagram.

Microscope Documentation and Image Capture Work Steps

1. Move the textile to the starting position for the microscope image capture series according to the image capture sampling diagram (Attachment 9).
2. Note degraded areas sketched on the hard copy colour image and determine alternate locations to perform image capture without loss of data required for analysis.
3. Position the textile mount under the microscope so that the weft yarns follow the x-axis and the warp yarns coincide with the y-axis.
4. Open the ‘weave structure’ folder in Image Analyze. Use the voice recorder and take an initial series of photos to document the following data required for calculations in the SQLite database application: binding weave structure, binding weft to pattern weft ratio (take several shots from the fragment edges to document this feature), number of lats per pass, and weft insertion sequence.
5. Open the ‘50x samples’ folder in Image Analyze. Place the textile at the location determined to be position 0,0 on the x-y axis under the microscope stand. Perform fine focus and capture image. Use the notches on the positioning slide to move the microscope 1 cm each on the x/y axes. Perform image stacking in areas where the textile is not flat. Repeat until the textile is comprehensively sampled in a diagonal direction.
6. For pattern unit documentation, be sure to position the textile so that the start of the pattern unit is in the 0,0 position.
7. Open the ‘area of interest’ folder in Image Analyze. Take photos of selected areas of interest.
8. Change the lens to 100x magnification. Open the ‘100x samples’ folder in Infinity Analyze. Place the textile at the location determined to be position 0,0 on the x-y axis under the microscope stand. Perform fine focus and capture image. Use the notches on the positioning slide to move the microscope 1 cm each on the x/y axes. Perform image stacking in areas where the textile is not flat. Repeat until the textile is comprehensively sampled in a diagonal direction.
9. Change the lens to 150x magnification. Open the ‘150x samples’ folder in Infinity Analyze. Place the textile at the location determined to be position 0,0 on the x-y axis under the microscope stand. Perform fine focus and capture image. Use the notches on the positioning slide to move the microscope 1 cm each on the x/y axes. Perform image stacking in areas where the textile is not flat. Repeat until the textile is comprehensively sampled in a diagonal direction.

Attachment 6.8

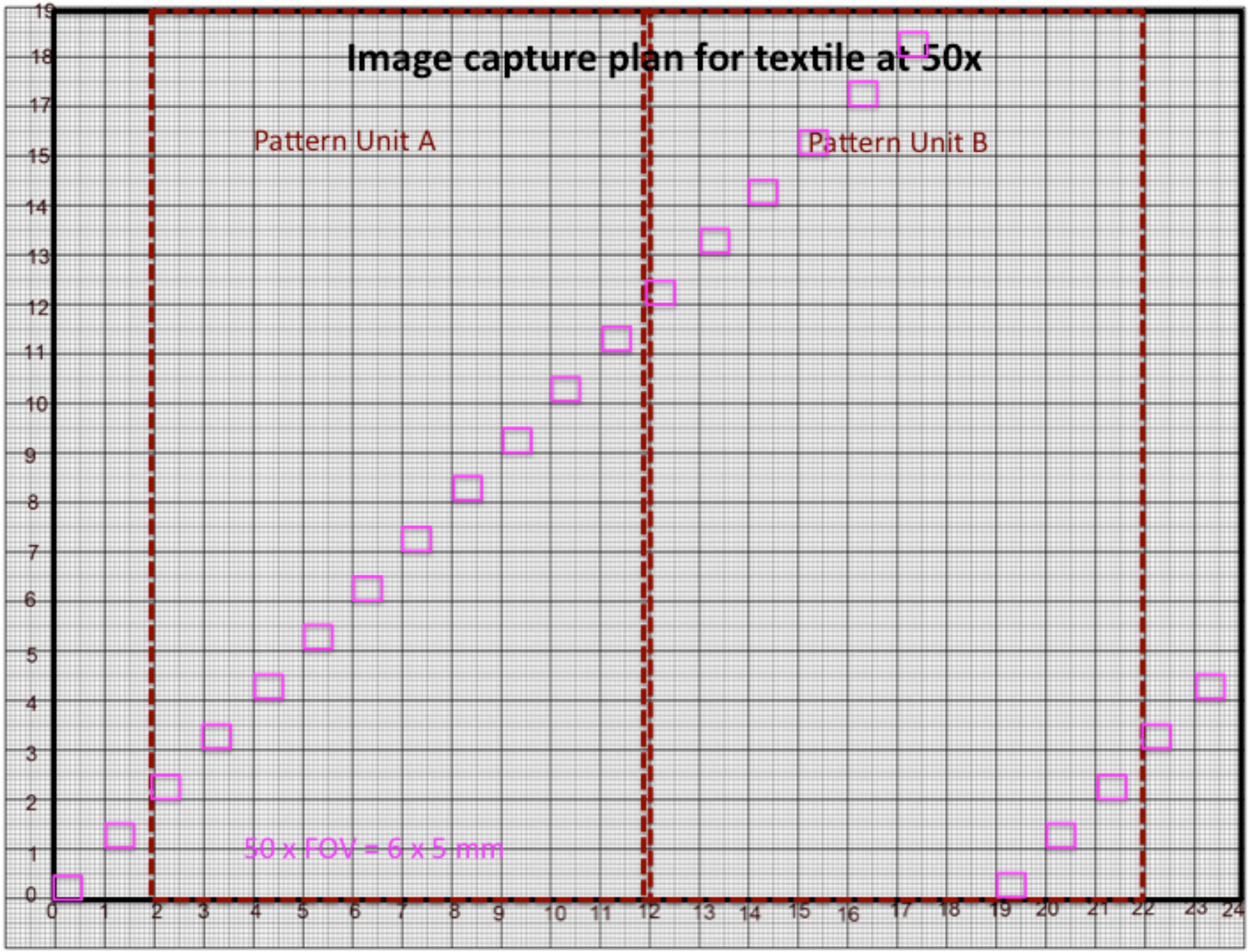
Image Capture Protocol

Post image capture processing

1. Immediately after completing the image capture session, copy the raw images to a back-up drive to be archived. Keep this file separate from the set of images to be subjected to analysis.
2. Review all images in the analysis set. Flag images to be loaded into the Textile Analysis user interface for processing and measurement.
3. Place flagged images into folders by textile, segregated by magnification level: 1, 50, 100 and 150. Move flagged photos into the appropriate folders.

Appendix 6.9

Image Capture Sampling Diagram



Appendix 6.10

Computer Vision Application Development Process

To prioritise work, the team assessed the project specifications from a computer vision perspective. The requirements for algorithm development were grouped into three distinct categories: 1) template matching, 2) parametric shape detection, and 3) change detection. Among these, developing a methodology for automated binding point detection proved to be the most difficult.

1) Template matching: A binding point occurs when a warp yarn moves to the surface over a weft to tie it in place. The network of binding points across the surface of the textile consolidates the material into a coherent unit. This network provides the basis for a two-dimensional coordinate system and is suitable for measurement purposes. While binding points are evident visually, there is considerable variation in appearance, both within a given textile and among the various silks in the study population. After considerable research and testing, the team implemented the Ciratefi template-matching model as the most effective solution. Appendix 6.11 shows a photograph of the Textile Analysis application interface for binding point detection at 50x magnification.

2) Parametric shape detection: To measure surface helix angle, the computer vision problem is to find an automated means to detect silk fibres as an arrangement of straight lines on randomly selected binding points. The task is to quantify the mean angle formed by all visible surface fibres in relation to the yarn axis. Among the methods tested, the team found that the Hough transform algorithm produced the most reliable results. By transforming line data into parametric space, this procedure quantifies the likelihood of points being on a line in real space.[1] A photograph of the user interface for surface helix angle measurement is included in appendix 6.12.

3) Change detection: The pattern matching tool combines two common image processing operations: image alignment and change detection. To align the images, the team implemented a search process that minimises the cumulative error resulting from two overlaid images. Complex computer vision tasks often implement similar techniques such as image registration to align images of the same scene through a transformation function.[2] Post alignment, a subtraction function is used to detect changes between two pattern blocks. The purpose is to suppress pattern features that do not change between images while highlighting those that differ.[3] In this application, a user defines an area of interest in a macro scale image. This area becomes a reference overlay that can be manipulated for comparison within the same or other photographs. The tool can be adjusted to exclude trivial variations that do not signify differences. Appendix 6.13 includes a photograph of the pattern-matching tool in the application user interface.

The team experimented briefly with the use of colour-matching tools for binding point detection. However, this approach alone proved unsuccessful for several reasons. In terms of imaging analysis, colour is not an intrinsic property and depends upon the spectral composition of the light source, surface reflective properties, and

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[1] Gonzalez and Woods 2008, 733-738.
[2] Gonzalez and Woods 2008, 89-90.
[3] Russ 2007, 319.

ambient lighting.[4] Colour recognition is even more problematic in archaeological textiles in which apparent colours may vary within the same textile because of degradation and exposure to other materials. Moreover, the wide range of colours used in different textiles precluded methodologies based principally on closely defined colour or greyscale factors.

During the software development process, the sixteen tests initially specified for the application were combined into seven user-selected menus, each corresponding to a set of tools to perform particular measurements. Menu options include: textile fragment dimensions, pattern unit dimensions, binding point-based measurements, pattern matching, binding point interior distance, yarn diameter measurements, and helix angle measurement. An additional menu stores notes and annotated images.

The system architecture for the textile analysis application was determined by user specifications and the operating environment required to perform particular calculations. The user interface portion of the application was written in Adobe ActionScript utilising event-driven architecture with support for persistent data storage.[5] The pattern-matching algorithm operates in this same environment. Textile images are available to the user in the form of collections, separated into folders by magnification level. The Ciratefi template matching algorithm and the Hough transform shape detection function are performed in Java.[6] The Glassfish server provides the intermediary between the two environments.[7] The user interface is integrated with a SQLite database to record all measurements performed in a session.[8] Standard statistical methods are applied to data for analysis and comparison. A diagram describing the system architecture is included in appendix 6.14.

[4] Alves de Araújoa and Kim 2011, 2.

[5] Adobe ActionScript is an object oriented programming language for various applications including animation and interactive interfaces.

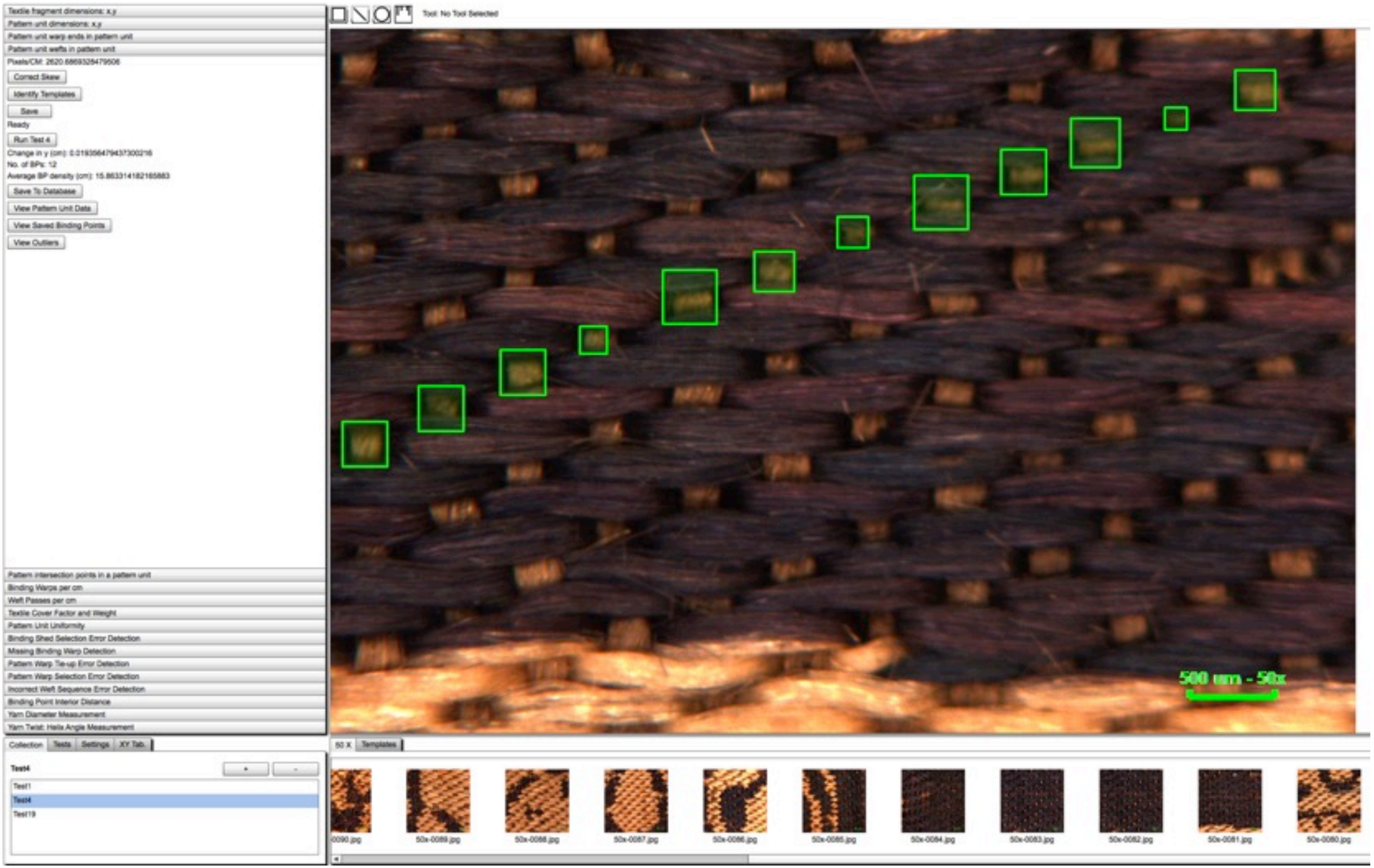
[6] Java is a general purpose, high-level computing language and platform widely used for application development.

[7] Oracle Glassfish enables portable and scalable interaction for enterprise applications.

[8] SQLite is an open source software library that implements a self-contained, serverless, zero configuration, transactional SQL database engine.

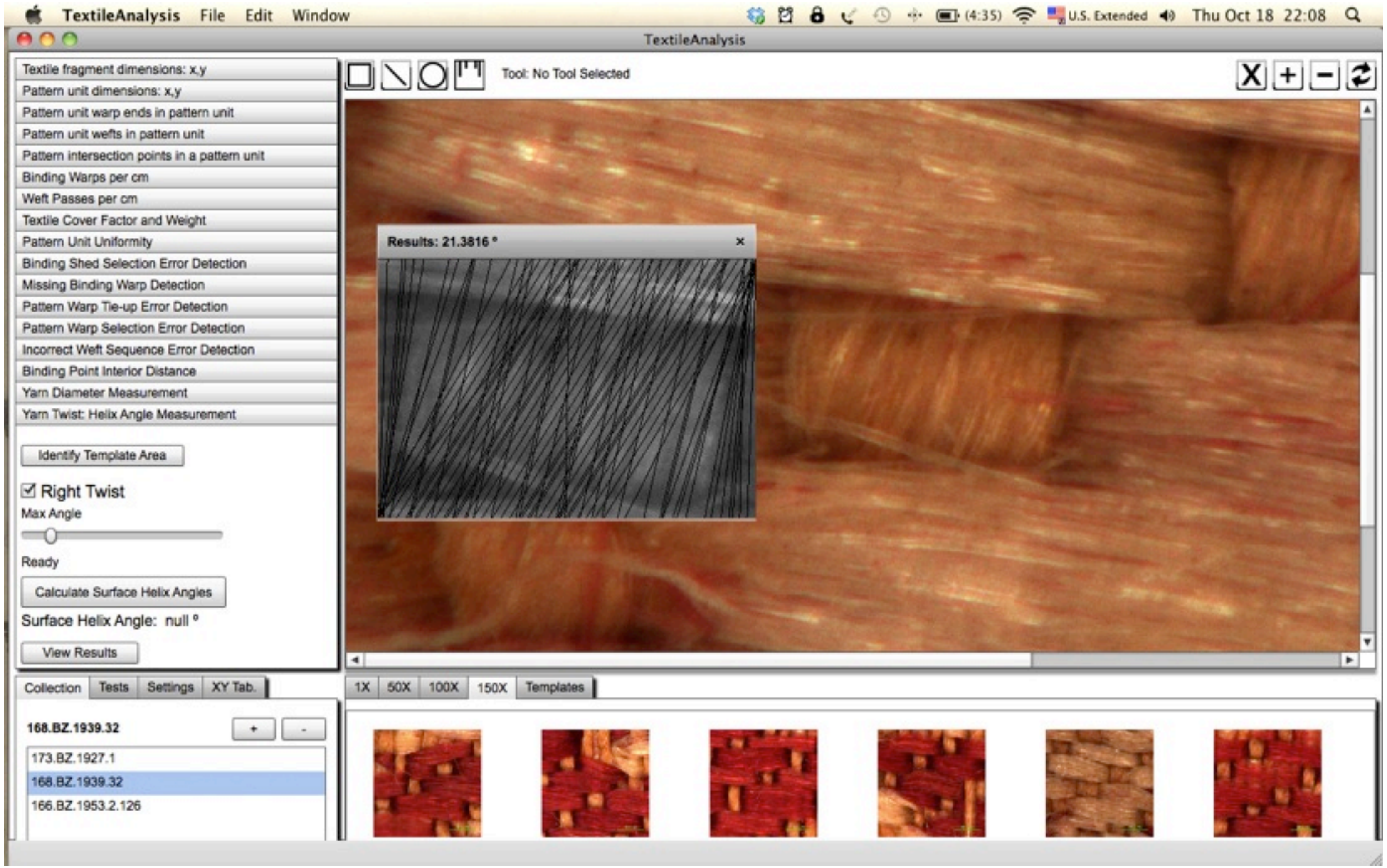
Appendix 6.11

Textile Application User Interface: Template Matching for Binding Point Detection



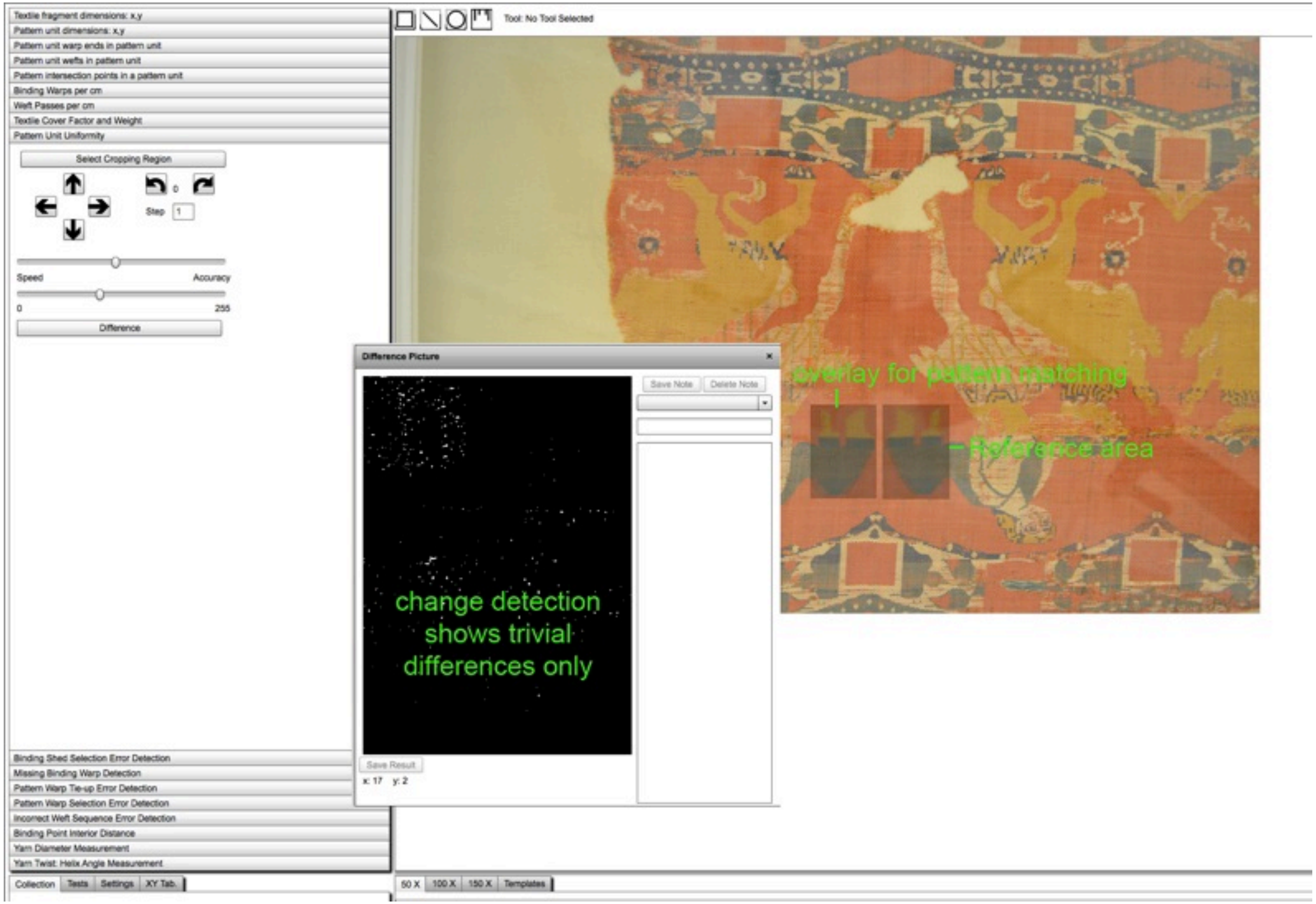
Appendix 6.12

Textile Application User Interface: Shape Detection to Measure Surface Helix Angle



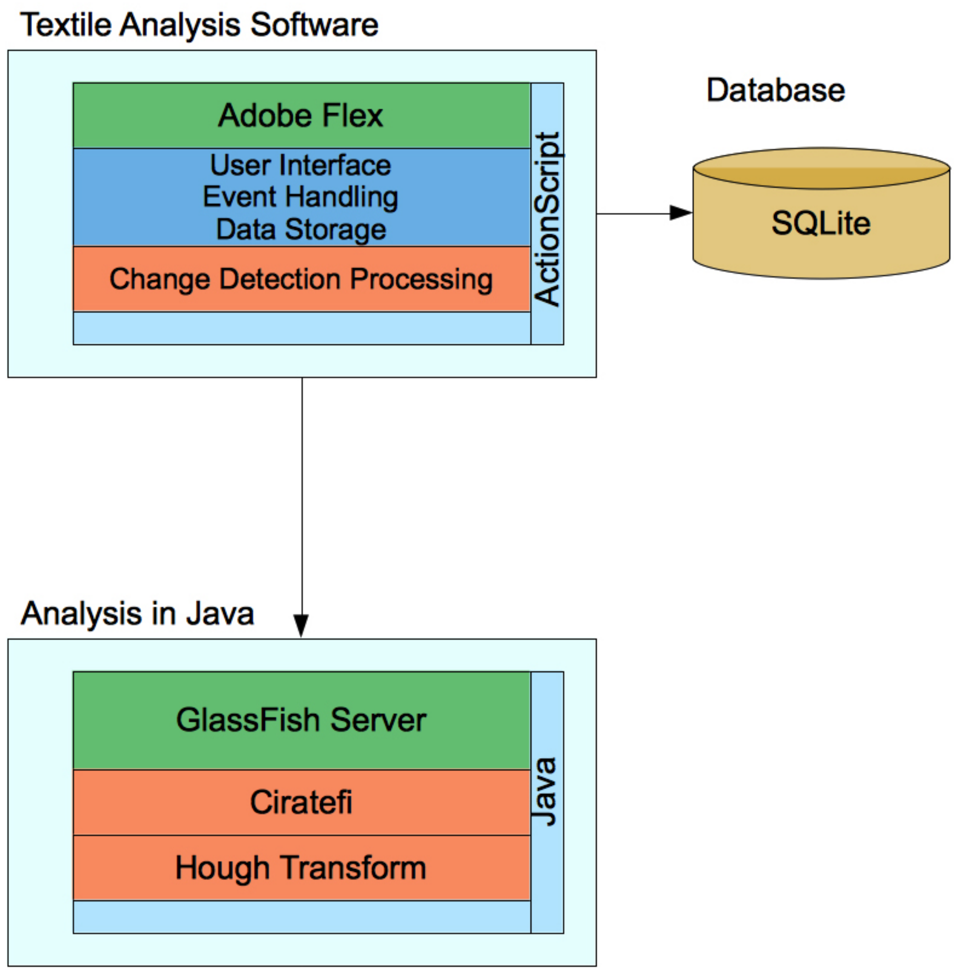
Appendix 6.13

Textile Application User Interface: Change Detection for Pattern Matching



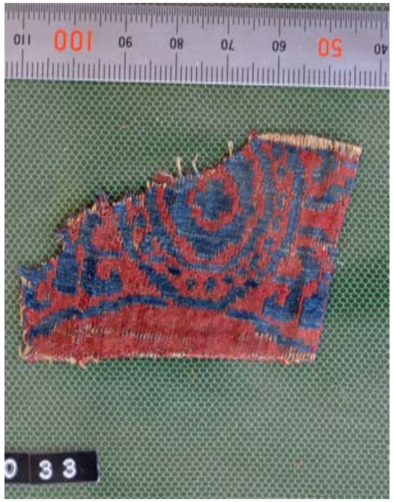
Appendix 6.14

Structural Overview of Textile Analysis Application



Appendix 7.1 - Study Group Textiles

BM 1895_8-10_15 7 samite



BM 1895_8-10_33 samite

BM 1895_8-10-20-31 samite

BM 18958_1032 samite

BM 1907_7-17_1 samite

BM 93_2_5_58 tablet weave

Appendix 7.1 - Study Group Textiles

BM AN267313001 lampas

BM AN34973001 samite

BM OA_10722 samite

BM OA756 samite

BMFA 01_8342 samite

BMFA 07_640a samite

Appendix 7.1 - Study Group Textiles

BMFA 09_127 samite

BMFA 11_90 samite

BMFA 15_1123 samite

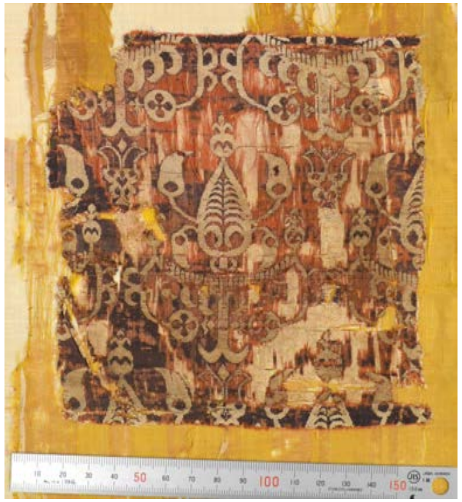
BMFA 15_385a-c samite

BMFA 25_159 samite

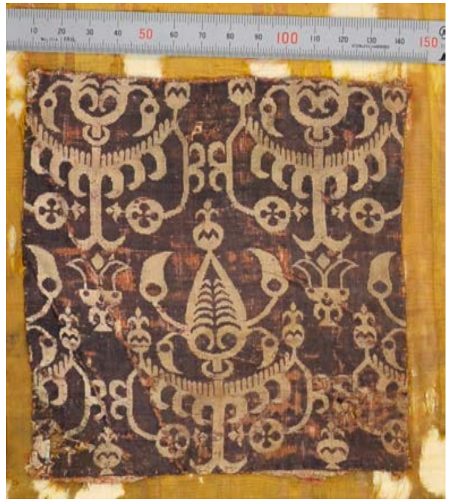
BMFA 25_196 samite

Appendix 7.1 - Study Group Textiles

BMFA 26_348a samite

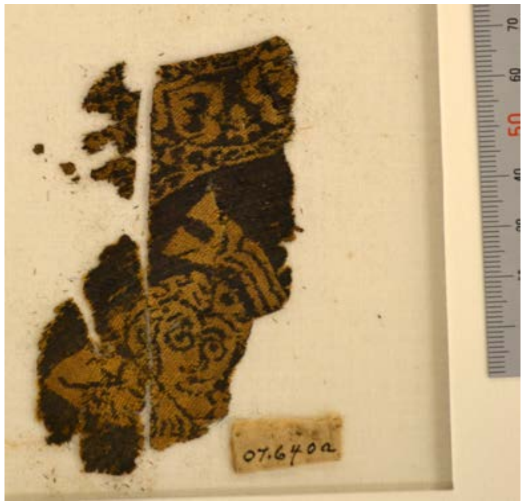


BMFA 26_348b samite



BMFA 26_348c samite

BMFA 26_794a samite

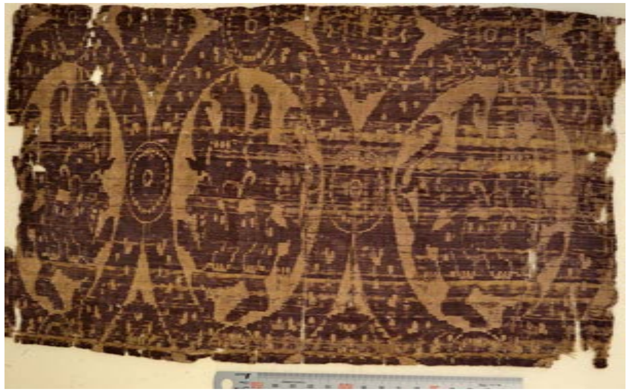


BMFA 07_640b samite

BMFA 31_129 samite

Appendix 7.1 - Study Group Textiles

BMFA 33_519 taquete



BMFA 33_648 samite

BMFA 35_73 samite

BMFA 47_1459 samite

BMFA 48_379 samite

BMFA 51_570 samite

Appendix 7.1 - Study Group Textiles

BMFA 96_354ab samite

CHMNYC 1902 1 210 gauze-complex

CHMNYC 1902 1 211 samite

CHMNYC 1902 1 212 samite

CHMNYC 1902 1 214 samite

CHMNYC 1902 1 220 lampas

Appendix 7.1 - Study Group Textiles

CHMNYC 1902 1 221 samite

CHMNYC 1902 1 222 samite

CHMNYC 1902 1 240 samite

CHMNYC 1902 1 244 samite

CHMNYC 1902 1 248 samite

CHMNYC 1902 1 978 taquete

Appendix 7.1 - Study Group Textiles

CMA 1939_505 samite

CMA 1947_192 samite

CMA 1950_2 samite

CMA 1950_518 supplementary weft

CMA 1950_520 samite

CMA 1951_87 samite

Appendix 7.1 - Study Group Textiles

CMA 1952_104 samite

CMA 1952_107 samite

CMA 1974_102 samite

CMA 1974_97 samite

CMA 1974_99 samite

CMA 1975_45 taquete

Appendix 7.1 - Study Group Textiles

CMA 1982_296 samite

CMA 1983_139 samite

CMA 1983_248 samite

CMA 1983_249 samite

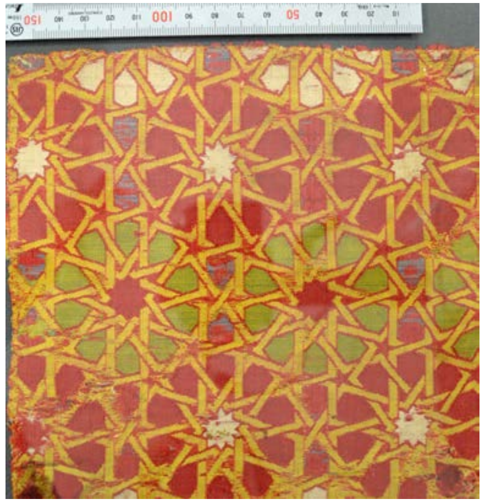
CMA 1983_264a samite

DIA 29_378 samite

Appendix 7.1 - Study Group Textiles

DIA 31_75 drap d'areste

DIA 36_22 printed



DIA 44_144 lampas

DIA 47_75 samite

DO 162 BZ 1939_33 samite

DO 163 BZ 1934_1 samite

Appendix 7.1 - Study Group Textiles

DO 165 BZ 1956_2 samite

DO 166 BZ 1953_2_126 samite

DO 167 BZ 1946_15 samite

DO 168 BZ 1939_32 samite

DO 169 BZ 1972_10 samite

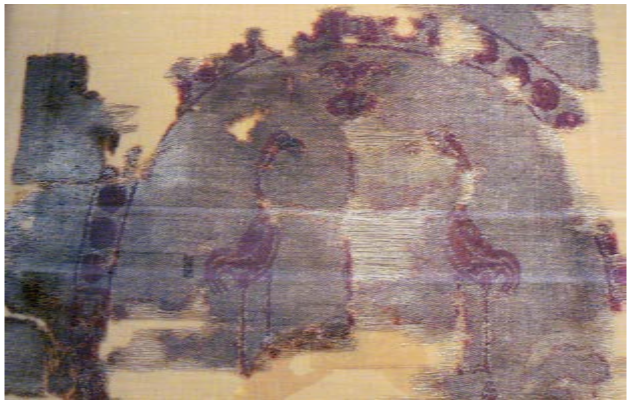
DO 173 BZ 1927_1 samite

Appendix 7.1 - Study Group Textiles

DO 174 BZ 1926_1 double weave

DO 175 BZ 1972_17 double weave

DO 2009 164 BZ1932_9 samite



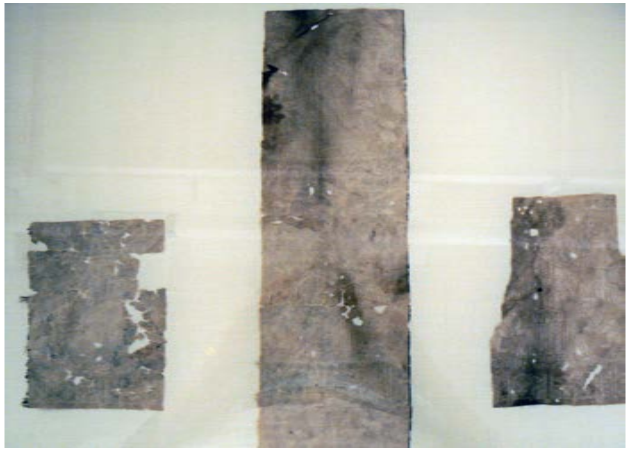
DO 2009 170 BZ1933_43 taquete

DO 2009 171 BZ1936_43 taquete

DO 2009 172 BZ1936_50 samite

Appendix 7.1 - Study Group Textiles

DO 2009 176 BZ1930_3 samite



DO 2009 177 BZ1929_101 lampas

DO 2009 178 BZ1937_25 lampas

DO 2009 179 BZ1939_7 lampas

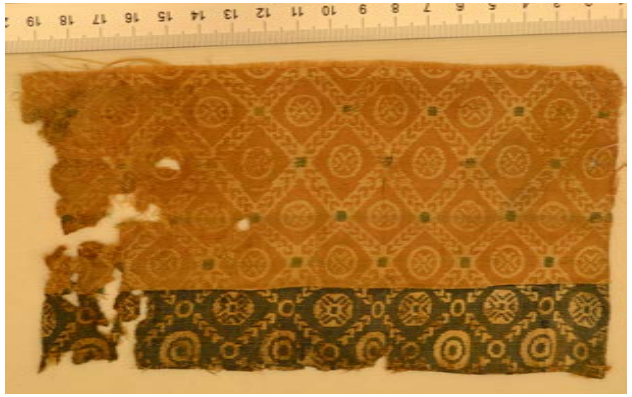
DO 2009 180 BZ1933_46 samite

DO 2009 181 BZ1933_11 lampas

Appendix 7.1 - Study Group Textiles

DO 2009 182
BZ1933_45 lampas

Kelsey 22683 samite



Kelsey 22683 samite

Kelsey 94151 samite

Kelsey 94152 samite

KTN 1019-01 gauze-complex

Appendix 7.1 - Study Group Textiles

KTN 1019-02 supplementary weft

KTN 1019-03 supplementary weft

KTN 1019-07b lampas

KTN 1146b samite

KTN 1160-03 samite

KTN 1375_6 samite

Appendix 7.1 - Study Group Textiles

KTN 156 taquete

KTN 1757 warp faced compound weave

KTN 650-14 samite

KTN 855a samite

KTN 942-01a samite

TMA 11_11 samite

Appendix 7.1 - Study Group Textiles

TMA 11_12 samite

TMA 11_16 samite

TMA 11_21 samite

TMA 11_22 samite

TMA 11_23 samite

TMA 11_26 samite

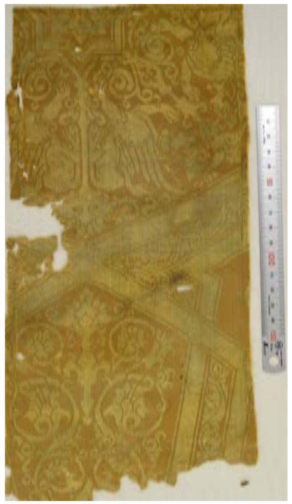
Appendix 7.1 - Study Group Textiles

TMA 11_28 taquete

TMA 11_29 taquete

TMA 11_30 samite

TMA 3_204 samite



TMA 3_212a lampas

TMA 3_212b lampas

Appendix 7.1 - Study Group Textiles

TMA 3_289 double weave

TMA 711_9 samite

TMA 73_663 double weave

Yale 1937_4618 samite

Yale 1937_4620 lampas

Yale 1939_635 samite

Appendix 7.1 - Study Group Textiles

Yale 1947_201e samite

Yale 1947_201g samite

Yale 1947_201h samite

Yale 1947_201i samite

Yale 1947_201j samite

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp		Main warp	Ratio		Alt weft	Twill/	Color/	Insert/	Avg/cm		Ratio:	PU X/Y	Warp/weft		
	Colour	Diam	diff	Bind: Ground	Ground: Pattern	diam diff	wrp ratio	disc	Grd weft	Warps	Wefts	bind warps: tot weft/cm	cm	steps	um	Use/Find
BM OA756	**1 Samite - alternate - single main warp - S twill - design parallel with warp**															
	**Subgroup: a Similar structure**															
	red brown faded	177		1.2	1.0	large diff	S	2	altern	21.7	53.9	0.4	4.9	1	461	
		Med fine					1:1		last	Med dense			2.8	2	186	Unknown
															1.0	
CMA 1950_520	**1 Samite - alternate - single main warp - S twill - design parallel with warp**															
	**Subgroup: a Similar structure**															
	red brown faded	135		0.9	0.9	large diff	S	3	altern	31.4	46.5	0.7	3.0		318	
		Fine					1:1		last	Very dense		High warp	11.3		215	Unknown
															0.6	
BMFA 48_379	**1 Samite - alternate - single main warp - S twill - design parallel with warp**															
	**Subgroup: b**															
	red brown faded	166		0.6	1.1		S	2	altern	14.8	23.8	0.6	9.2	1	676	
		Fine		Thin warp			1:1		last	Med loose			4.6	2	840	Unknown
															0.2	
BMFA 11_90	**2 Samite - alternate - single main warp - S twill - very fine warp and weft**															
	**Subgroup: a**															
	brown medium	121		1.0	1.0	large diff	S	2	altern	31.6	59.7	0.5	4.1	1	317	
		Fine					1:1		last	Very dense			3.1	2	335	Unknown
															0.4	
BMFA 33_519	**3 Taquete - alternate - single or multiple main warp - bi-colour or polychrome**															
	**Subgroup: a**															
	green light	280	Main white S	0.6	0.0			2	altern	14.5	16.8	0.9	1.5	1	689	
		Med coarse		Thin warp			1:1		n/a	Med loose		High warp	1.8	2	1194	Unknown
															0.2	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp: Colour	Bind warp: Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm: Warps	Avg/cm: Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft: steps	Warp/weft: um	Use/Find
CHMNYC 1902 1 978	**3 Taquete - alternate - single or multiple main warp - bi-colour or polychrome**															
	**Subgroup: b**															
	white cream	156	Yes	0.7	0.8			5	altern	11.6	23.8	0.5	1.9	1	862	
		Fine		Thin warp	Thin grd		1-2:4-6	5	n/a	Med loose			24.3	24	1680	Badia collection
															0.1	
CMA 1975_45	**3 Taquete - alternate - single or multiple main warp - bi-colour or polychrome**															
	**Subgroup: c**															
	brown dark	216		1.0	1.2			3	altern	19.8	35.0	0.6		1	506	
		Med			Thick grd		1:2		first	Med				2	571	Unknown
															0.4	
CHMNYC 1902 1 248	**4 Samite - alternate - single main warp - S or Z twill - non-representational**															
	**Subgroup: a Similar design**															
	brown light tan	191		0.9	1.2	large diff	Z	3	altern	18.9	33.3	0.6	1.0	1	529	
		Med fine			Thick grd		1:1	1	n/a	Med			2.7	2	601	Cemetery
															0.3	
Kelsey 22683	**4 Samite - alternate - single main warp - S or Z twill - non-representational**															
	**Subgroup: a Similar design**															
	brown light tan	264		1.2	1.0		Z	2	altern	17.4	37.6	0.5	1.4	1	574	
		Med coarse		Thick warp			1:1		n/a	Med			1.5	2	532	Cemetery
															0.5	
Kelsey 22683	**4 Samite - alternate - single main warp - S or Z twill - non-representational**															
	**Subgroup: a Similar design**															
	brown light tan	226		1.1	0.9		Z	3	altern	18.1	31.2	0.6	1.7	1	552	
		Med					1:1		n/a	Med			6.5	2	641	Cemetery
															0.4	

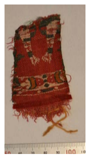
Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp Colour	Bind warp Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
DIA 29_378	**4 Samite - alternate - single main warp - S or Z twill - non-representational**															
	**Subgroup: b Similar design**															
	brown light tan	227		1.0	1.0		S	2	altern	17.0	38.7	0.4	1.1	1	589	
		Med					1:1		n/a	Med			1.5	2	517	Cemetery
															0.4	
BM OA_10722	**4 Samite - alternate - single main warp - S or Z twill - non-representational**															
	**Subgroup: c**															
	white cream	160		1.5	0.9		S	2	altern	26.0	65.8	0.4	1.0	1	384	
		Fine		Thick warp			1:1		n/a	Dense			1.1	2	304	Unknown
															0.5	
BMFA 31_129	**5 Samite - alternate - single main warp - S twill - bi-colour**															
	**Subgroup: a Similar structure**															
	brown light tan	246		1.0	0.9		S	2	altern	20.7	32.2	0.6	8.3	5	2417	Applied
		Med coarse					1:1		last	Med			11.8	4	1241	Cemetery
															0.2	
CMA 1982_296	**5 Samite - alternate - single main warp - S twill - bi-colour**															
	**Subgroup: a Similar design**															
	brown light tan	245		1.3	1.0		S	2	altern	18.7	44.0	0.4	9.2	2	1068	Applied
		Med coarse		Thick warp			1:1		last	Med			18.0	4	910	Cemetery
															0.3	
DO 169 BZ 1972_10	**5 Samite - alternate - single main warp - S twill - bi-colour**															
	**Subgroup: a Similar design**															
	brown light tan	242		1.2	0.9		S	2	altern	20.0	34.2	0.6	8.7	2	999	Applied
		Med coarse					1:1		last	Med			14.5	4	1171	Cemetery
															0.2	

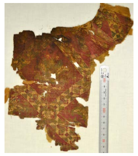
Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

Textile	Bind warp: Colour	Bind warp: Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
Kelsey 94151	**5 Samite - alternate - single main warp - S twill - bi-colour**															
	**Subgroup: b Divided - same textile**															
	red faded	259		1.4	1.0		Z	2	altern	19.8	32.6	0.6		2	1010	Applied
		Med coarse		Thick warp			1:1		last	Med				4	1228	Cemetery
															0.2	
TMA 11_23	**5 Samite - alternate - single main warp - S twill - bi-colour**															
	**Subgroup: b Divided - same textile**															
	red faded	260		1.3	0.9		Z	2	altern	0.0	0.0	?	8.9			Applied
		Med coarse		Thick warp			1:1		last	Loose		High warp	15.1			Cemetery
															?	
BMFA 47_1459	**5 Samite - alternate - single main warp - S twill - bi-colour**															
	**Subgroup: c**															
	red faded	177	Some different	0.8	1.1		S/Z	2	altern	12.4	34.7	0.4	8.4	1	805	
		Med fine		Thin warp			1:1 or 2		first	Med loose			16.9	2	577	Unknown
															0.3	
TMA 11_26	**5 Samite - alternate - single main warp - S twill - bi-colour**															
	**Subgroup: d**															
	brown light tan	710		1.2	1.1	yes	S	2	altern	18.6	34.0	0.5	8.3	1	539	Applied
		Coarse		Thick warp			1:1		last	Med			15.7	2	589	Cemetery
															1.2	
Yale 1947_201g	**6 Samite - alternate - single main warp - S twill - polychrome**															
	**Subgroup: a Divided - same textile**															
	red brown faded	267		1.2	1.0		S	3	altern	16.7	31.7	0.5	9.4	1	598	Applied
		Med coarse		Thick warp			1:1		first	Med			20.4	2	632	Cemetery
															0.4	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp Colour	Bind warp Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
Yale 1947_201h	**6 Samite - alternate - single main warp - S twill - polychrome**															
	**Subgroup: a**	**Divided - same textile**														
	red brown faded	235		1.0	1.1		S	3	altern	16.0	31.0	0.5	9.6	1	624	Applied
		Med					1:1		first	Med			20.1	2	645	Cemetery
															0.4	
Yale 1947_201e	**6 Samite - alternate - single main warp - S twill - polychrome**															
	**Subgroup: b**	**Related - same structure and**														
	brown light tan	257		1.2	1.2		S	3	altern	18.4	32.3	0.6		1	543	Applied
		Med coarse			Thick grd		1:1		first	Med				2	618	Cemetery
															0.4	
Yale 1947_201i	**6 Samite - alternate - single main warp - S twill - polychrome**															
	**Subgroup: b**	**Divided - same textile**														
	red brown faded	224		0.9	1.0		S	3	altern	19.8	28.5	0.7	8.3	1	506	Applied
		Med					1:1		first	Med		High warp	16.0	2	702	Cemetery
															0.3	
Yale 1947_201j	**6 Samite - alternate - single main warp - S twill - polychrome**															
	**Subgroup: b**	**Divided - same textile**														
	red brown faded	235		1.0	1.0		S	3	altern	19.2	25.4	0.8		1	521	Applied
		Med					1:1		first	Med		High warp		2	787	Cemetery
															0.3	
CMA 1974_97	**6 Samite - alternate - single main warp - S twill - polychrome**															
	**Subgroup: c**	**Similar design**														
	red	302		1.3	1.0		S	4	altern	15.0	51.8	0.3		1	668	
		Coarse		Thick warp			1:1		first	Med loose		Low warp		2	386	Shrine
															0.8	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp Colour	Bind warp Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
DO 163 BZ 1934_1	**6 Samite - alternate - single main warp - S twill - polychrome**															
	**Subgroup: c Similar design**															
	red	299		1.0	1.1		S	5	altern	15.3	28.6	0.5	12.1	1	652	
		Coarse					1:1	2	first	Med			21.1	2	700	Unknown
															0.4	
TMA 11_11	**6 Samite - alternate - single main warp - S twill - polychrome**															
	**Subgroup: d Similar structure**															
	red brown faded	209		1.3	0.9		S	4	altern	20.4	46.3	0.4		1	490	Tailoring
		Med		Thick warp			1:1		first	Med				2	432	Cemetery
															0.5	
TMA 11_12	**6 Samite - alternate - single main warp - S twill - polychrome**															
	**Subgroup: d Similar structure**															
	red faded	150		1.1	0.8		S	3	altern	21.4	48.1	0.4	3.9	1	467	Tailoring
		Fine			Thin grd		1:1		last	Med dense			7.8	2	416	Cemetery
															0.4	
CHMNYC 1902 1 244	**7 Samites – alternate - single main warp - Z twill - polychrome**															
	**Subgroup: a**															
	brown light tan	136		0.8	1.0		Z	3 ?	altern	14.0	44.4	0.3	8.0		713	
		Fine					1:1		last	Med loose		Low warp	21.7		451	
															0.3	Badia collection
CMA 1947_192	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: a Divided - same textile**															
	brown light tan	275		1.0	1.1		Z	2	rever	16.5	26.7	0.6	11.1	1	605	Applied
		Med coarse					1:1		last	Med			21.5	2	749	Cemetery
															0.4	

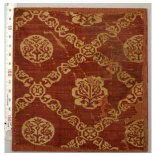
Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp		Main warp	Ratio		Alt weft	Twill/	Color/	Insert/	Avg/cm		Ratio:	PU X/Y	Warp/weft		
	Colour	Diam	diff	Bind: Ground	Ground: Pattern	diam diff	wrp ratio	disc	Grd weft	Warps	Wefts	bind warps: tot weft/cm	cm	steps	um	Use/Find
DO 168 BZ 1939_32	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: a Divided - same textile**															
	brown light tan	280		1.1	1.0		Z	2	rever	18.1	31.7	0.6	10.7	1	553	Applied
		Coarse					1:1		last	Med			20.4	2	631	Cemetery
															0.4	
BMFA 07_640a	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: b Similar design**															
	brown light tan	241		1.3	0.9		Z	2	rever	20.4	37.2	0.5		1	491	Applied
		Med coarse		Thick warp			1:1		last	Med				2	537	Cemetery
															0.4	
BMFA 07_640b	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: b Similar design**															
	brown light tan	257		1.4	0.9		Z	2	rever	18.3	41.3	0.4		1	547	
		Med coarse		Thick warp			1:1		last	Med				2	484	Cemetery
															0.5	
BMFA 51_570	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: b Similar design**															
	brown light tan	225		1.1	1.0	large diff	Z	2	rever	22.0	35.0	0.6	12.0	1	454	Applied
		Med					1:1		last	Med dense			22.0	2	572	Cemetery
															0.4	
CMA 1952_104	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: b Similar design**															
	brown medium	224		1.2	1.0		Z	2	rever	19.0	31.4	0.6	10.9	1	525	Applied
		Med					1:1		last	Med			19.2	2	638	Cemetery
															0.4	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp: Colour	Bind warp: Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
DO 167 BZ 1946_15	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: b Similar design**															
	brown medium	229		1.3	0.9		Z	2	rever	20.9	37.1	0.6	9.3	1	478	Applied
		Med		Thick warp			1:1		last	Med			21.6	2	539	Cemetery
															0.4	
TMA 11_16	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: b Similar design**															
	brown medium	226		1.2	0.9	large diff	Z	2	rever	20.2	41.1	0.5	10.2	1	496	Applied
		Med		Thick warp			1:1		last	Med			19.3	2	487	Cemetery
															0.5	
BMFA 09_127	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: c Similar design**															
	brown dark	359		1.5	0.9		Z	2	rever	14.9	29.7	0.5		1	670	
		Coarse		Thick warp			1:1		last	Med loose				2	674	Cemetery
															0.5	
BMFA 15_1123	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: c Similar design**															
	brown medium	265		1.2	0.9		Z	2	rever	17.1	39.0	0.4		1	584	Applied
		Med coarse		Thick warp			1:1		last	Med				2	513	Cemetery
															0.5	
CMA 1983_139	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: c Similar design**															
	brown medium	282		1.5	1.0		Z	2	rever	15.2	33.4	0.5	5.7	1	658	
		Coarse		Thick warp			1:1		last	Med			7.8	2	598	Cemetery
															0.5	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp Colour	Bind warp Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
DIA 47_75	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: c Similar design**															
	brown medium	270		1.3	0.8		Z	2	rever	15.1	35.1	0.4	6.5	1	664	Applied
		Med coarse		Thick warp	Thin grd		1:1		last	Med			10.1	2	571	Cemetery
															0.5	
TMA 11_21	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: c Similar design**															
	brown light tan	289		1.6	1.0		Z	2	rever	17.1	36.6	0.5	4.7	1	585	
		Coarse		Thick warp			1:1		last	Med			8.0	2	547	Cemetery
															0.5	
Yale 1939_635	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: c Similar design**															
	brown light tan	224		1.2	0.9		Z	2	rever	17.9	35.4	0.5	5.3	1	560	
		Med		Thick warp			1:1		last	Med			6.1	2	565	Cemetery
															0.4	
BMFA 26_794a	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: d Similar design**															
	brown dark	297		1.3	0.9		Z	2	rever	17.4	30.1	0.6	8.6	1	574	Applied
		Coarse		Thick warp			1:1		last	Med			18.2	2	664	Cemetery
															0.4	
CMA 1952_107	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: d Similar design**															
	brown light tan	229		1.0	0.9		Z	2	rever	19.6	27.6	0.7	9.4	1	511	Applied
		Med					1:1		last	Med		High warp	19.6	2	725	Cemetery
															0.3	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp Colour	Bind warp Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
CMA 1983_248	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: d Similar design**															
	brown medium	215		0.7	1.3		Z	2	rever	21.1	28.2	0.7	8.3	1	474	Applied
		Med		Thin warp	Thick grd		1:1		last	Med dense		High warp	15.3	2	710	Cemetery
															0.3	
CMA 1983_249	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: d Similar design**															
	brown dark	269		1.1	1.0		Z	2	rever	19.7	29.4	0.7	5.0	1	509	Applied
		Med coarse					1:1		last	Med		High warp	12.0	2	681	Cemetery
															0.4	
DO 166 BZ 1953_2_126	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: d Similar design**															
	brown dark	248		1.2	1.0		S/Z	2	rever	21.5	30.6	0.7	9.1	1	465	Applied
		Med coarse					1:1		last	Med dense		High warp	18.0	2	653	Cemetery
															0.4	
CMA 1939_505	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: e Similar structure**															
	brown light tan	289		1.3	0.9		Z	2	rever	18.3	33.0	0.6		1	546	Applied
		Coarse		Thick warp			1:1		last	Med				2	605	Cemetery
															0.5	
CMA 1951_87	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: e Similar structure**															
	brown light tan	334		1.4	1.0		Z	2	rever	18.3	28.3	0.6	5.7	1	546	Applied
		Coarse		Thick warp			1:1		last	Med			13.1	2	707	Cemetery
															0.5	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp Colour	Bind warp Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
CMA 1983_264a	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: f**															
	red faded	260		1.0	1.1		Z	2	rever	16.1	29.7	0.5		1	623	Applied
		Med coarse					1:1		last	Med				2	674	Cemetery
															0.4	
BMFA 15_385a-c	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: g**															
	red faded	314		1.3	0.9		Z	2	rever	17.1	30.0	0.6	10.8		585	Applied
		Coarse		Thick warp			1:1		first	Med			19.7		667	Cemetery
															0.5	
TMA 11_22	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: h**															
	brown dark	298		1.1	1.2		Z	2	rever	16.2	28.4	0.6		1	615	
		Coarse			Thick grd		1:1		n/a	Med				2	705	Unknown
															0.4	
Kelsey 94152	**8 Samite – reverse - single main warp - Z twill - bi-colour**															
	**Subgroup: i**															
	brown light tan	277		1.2	0.9		Z	2	rever	20.1	27.4	0.7	10.0	1	497	Applied
		Med coarse					1:1		first	Med		High warp	18.7	2	731	Cemetery
															0.4	
BM AN34973001	**9 Samite - reverse - single main warp - S twill - bi-colour**															
	**Subgroup: a Similar design**															
	brown dark	280		1.3	0.9		S/Z	2	rever	19.4	33.6	0.6	11.7	1	516	Applied
		Med coarse		Thick warp			1:1		first	Med			30.9	2	595	Cemetery
															0.5	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp Colour	Bind warp Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
DO 165 BZ 1956_2	**9 Samite - reverse - single main warp - S twill - bi-colour**															
	**Subgroup: a Similar design**															
	brown dark	316		1.1	1.0	Yes	S	2	rever	18.7	24.1	0.8	8.9	1	536	
		Coarse					1:1		n/a	Med		High warp	11.8	2	830	Cemetery
															0.4	
BM 1907_7-17_1	**9 Samite - reverse - single main warp - S twill - bi-colour**															
	**Subgroup: b**															
	brown dark	228		1.1	1.1		S	2	rever	13.4	29.2	0.5			744	
		Med					1:1		last	Med loose					685	Shrine
															0.3	
BMFA 25_196	**10 Samite - reverse - single main warp - S twill - polychrome**															
	**Subgroup: a**															
	red	222	main spun, plied S	1.1	1.2		S	3	rever	16.6	36.9	0.5	6.4	1	602	Applied
		Med			Thick grd		1:1		last	Med			13.4	2	542	Cemetery
															0.4	
DO 162 BZ 1939_33	**10 Samite - reverse - single main warp - S twill - polychrome**															
	**Subgroup: b**															
	natural	123		1.0	0.8		S	3	rever	26.0	49.3	0.5	3.6	1	384	
		Fine					1:1	1	n/a	Dense			12.8	2	406	Unknown
															0.3	
DO 2009 164 BZ1932_9	**10 Samite - reverse - single main warp - S twill - polychrome**															
	**Subgroup: c**															
	red	436		?	0.0		S	3	n/a	16.0	28.2	0.6	28.8		627	Applied
		Coarse		Thick warp			1:1		n/a	Med			23.5		709	Cemetery
															0.6	

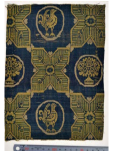
Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp		Main warp	Ratio		Alt weft	Twill/	Color/	Insert/	Avg/cm		Ratio:	PU X/Y	Warp/weft		
	Colour	Diam	diff	Bind: Ground	Ground: Pattern	diam diff	wrp ratio	disc	Grd weft	Warps	Wefts	bind warps: tot weft/cm	cm	steps	um	Use/Find
TMA 711_9	**10 Samite - reverse - single main warp - S twill - polychrome**															
	**Subgroup: d**															
	red faded	244		1.1	1.0		S	4	rever	18.4	28.8	0.6	13.6	1	545	
		Med coarse					1:1	2	first	Med			26.2	2	695	Unknown
															0.4	
BMFA 01_8342	**11 Samite - alternate - multiple main warp - S twill - bi-colour**															
	**Subgroup: a Divided - same textile**															
	blue medium	191	main thicker, black	0.7	0.0		S	2	altern	10.4	31.7	0.3		1	1921	Applied
		Med fine		Thin warp			1:2		first	Loose		Low warp		2	631	Cemetery
															0.3	
BMFA 25_159	**11 Samite - alternate - multiple main warp - S twill - bi-colour**															
	**Subgroup: a Divided - same textile**															
	blue medium	150	main thicker, black	0.6	0.0		S	2	altern	10.5	30.4	0.3	6.6	1	1899	Applied
		Fine		Thin warp			1:2		last	Loose			9.3	2	658	Cemetery
															0.2	
BMFA 26_348a	**11 Samite - alternate - multiple main warp - S twill - bi-colour**															
	**Subgroup: b Divided - same textile**															
	purple with red undertones	155		0.9	1.0		S	2	altern	32.7	40.6	0.8	2.6	1	305	Applied
		Fine					1:2		last	Very dense		High warp	12.3	2	493	Cemetery
															0.3	
BMFA 26_348b	**11 Samite - alternate - multiple main warp - S twill - bi-colour**															
	**Subgroup: b Divided - same textile**															
	purple with red undertones	176		1.0	0.9		S	2	altern	26.4	38.2	0.7	3.5	1	379	Applied
		Med fine					1:2		last	Dense		High warp	12.3	2	523	Cemetery
															0.3	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp		Main warp	Ratio		Alt weft	Twill/	Color/	Insert/	Avg/cm		Ratio:	PU X/Y	Warp/weft		
	Colour	Diam	diff	Bind: Ground	Ground: Pattern	diam diff	wrp ratio	disc	Grd weft	Warps	Wefts	bind warps: tot weft/cm	cm	steps	um	Use/Find
BMFA 26_348c	**11 Samite - alternate - multiple main warp - S twill - bi-colour**															
	**Subgroup: b Divided - same textile**															
	purple with red undertones	169		0.9	0.9		S	2	altern	24.9	36.3	0.7	3.5	1	402	Applied
		Fine					1:2		last	Med dense		High warp	12.3	2	551	Cemetery
															0.3	
BMFA 96_354ab	**12 Samite - alternate - multiple main warp - S twill - polychrome**															
	**Subgroup: a**															
	brown medium	198		0.8	0.9		S	4	altern	16.4	23.3	0.7	10.4	2	1218	
		Med fine		Thin warp			1:2	1	last	Med		High warp	24.6	2	857	Cemetery
															0.2	
CHMNYC 1902 1 211	**12 Samite - alternate - multiple main warp - S twill - polychrome**															
	**Subgroup: b**															
	brown light tan	210	Yes	0.6	1.0		S	4	altern	14.3	21.2	0.7	14.3	23	1401	
		Med		Thin warp			1:3	1	last	Med loose		High warp	15.1	2	942	Badia collection
															0.2	
BMFA 33_648	**13 Samite - reverse - multiple main warp - S twill - bi-colour**															
	**Subgroup: a**															
	purple faded	185		1.2	0.9		S	2	rever	17.3	47.2	0.4	11.8	1	578	
		Med fine		Thick warp			1:2		first	Med			18.8	4	848	Unknown
															0.2	
CMA 1974_102	**13 Samite - reverse - multiple main warp - S twill - bi-colour**															
	**Subgroup: b**															
	brown medium	163		0.9	0.8		S	2	rever	12.6	39.4	0.3	2.4	1	794	
		Fine			Thin grd		1:2		n/a	Med loose		Low warp	2.4	2	507	Shrine
															0.3	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp: Colour	Bind warp: Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm: Warps	Avg/cm: Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft: steps	Warp/weft: um	Use/Find
CHMNYC 1902 1 212	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: a Similar structure**															
	beige	194	Yes	0.8	1.0		S	4	rever	14.3	32.2	0.4	12.5	2	1397	
		Med fine					1:2		first	Med loose			16.2	4	1241	Badia collection
															0.2	
CHMNYC 1902 1 214	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: a Similar structure**															
	brown light tan	220		1.1	1.1		S	4	rever	15.1	34.9	0.4	16.8	2	1326	
		Med					1:2		first	Med			15.6	4	1148	Badia collection
															0.2	
CHMNYC 1902 1 221	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: a Similar structure**															
	red faded	208		0.7	0.9		S	4	rever	13.4	26.0	0.5	42.7	2	1494	
		Med fine		Thin warp			1:2 or 3		first	Med loose			39.4	4	1540	Badia collection
															0.1	
CHMNYC 1902 1 222	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: a Similar structure**															
	natural	193		1.0	1.0		S	3	rever	13.6	45.6	0.3	15.8	1	735	
		Med fine					1:2		first	Med loose		Low warp	50.9	2	438	Badia collection
															0.4	
DO 173 BZ 1927_1	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: b**															
	brown dark	203		1.0	1.1		S	4	rever	17.8	31.7	0.6	13.5	1	561	
		Med fine					1:2		first	Med			15.5	2	631	Unknown
															0.3	

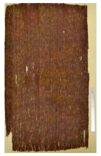
Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

Sample	Bind warp: Colour	Bind warp: Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
DO 2009 176 BZ1930_3	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: c**															
	brown light tan	220		1.0	0.9		S	3	rever	18.2	53.1	0.3		1	550	
		Med					1:2		first	Med		Low warp		2	377	Unknown
															0.6	
TMA 3_204	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: d**															
	blue medium	183	Yes	1.3	0.9		S	7	rever	17.6	50.2	0.3		2	1139	
		Med fine		Thick warp			1:2		n/a	Med				4	797	Unknown
															0.2	
BM 1895_8-10_15 7	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: e Similar structure**															
	brown light tan	76		1.1	0.9		S	3	rever	16.3	44.8	0.4		1	613	
		Fine					1:2		last	Med				2	447	Shrine
															0.2	
BM 1895_8-10_33	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: e Similar structure**															
	brown light tan	198		1.2	1.0		S	2	rever	15.4	53.7	0.3		1	651	
		Med fine					1:2		n/a	Med		Low warp		3	558	Shrine
															0.4	
BM 18958_1032	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: f Similar structure**															
	yellow gold	226	main thinner, brown	0.7	1.0		S	4	rever	13.0	24.4	0.5		1	771	Tailoring
		Med		Thin warp			1:2		n/a	Med loose				2	819	Shrine
															0.3	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp Colour	Bind warp Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
CMA 1974_99	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: f Similar structure**															
	natural	184		0.9	1.0		S	3	rever	17.5	40.2	0.4	16.8	2	1146	
		Med fine					1:2		first	Med			32.4	4	996	Unknown
															0.2	
DO 2009 180 BZ1933_46	**14 Samite - reverse - multiple main warp - S twill - polychrome**															
	**Subgroup: f Similar structure**															
	brown light tan	226		?	0.0		S	3	rever	11.9	51.2	0.2	11.4	1	843	
		Med		Thick warp			1:2		last	Med loose		Low warp	50.5	2	391	Unknown
															0.6	
BM 1895_8-10-20-31	**15 Samite - reverse - multiple main warp - Z twill - polychrome**															
	**Subgroup: a**															
	red	268	main inferior quality, brown	1.0	1.0		Z	4	rever	13.4	30.3	0.4		2	1493	
		Med coarse					1:2	3	n/a	Med loose				2	660	Shrine
															0.4	
CMA 1950_2	**16 Samite - reverse - single main warp - 1/3 S twill - with metal foil**															
	**Subgroup: a**															
	red faded	184		0.9	1.0		S	4	rever	32.3	25.9	1.2	26.8	1	310	
		Med fine					1:1	2	last	Very dense		High warp	48.6	2	772	Unknown
															0.2	
BMFA 35_73	**17 Samite - alternate - multiple main warp - S or Z twill - no twist binding warp**															
	**Subgroup: a**															
	red faded	150		0.7	1.1		S	2	altern	10.9	37.3	0.3	5.6	1	916	
		Fine		Thin warp			1:2		last	Loose		Low warp	14.3	2	536	Unknown
															0.3	

Appendix 7.2 - Mediterranean and Near East Weft-faced Compound Weave Data

	Bind warp Colour	Bind warp Diam	Main warp diff	Ratio Bind: Ground	Ratio Ground: Pattern	Alt weft diam diff	Twill/ wrp ratio	Color/ disc	Insert/ Grd weft	Avg/cm Warps	Avg/cm Wefts	Ratio: bind warps: tot weft/cm	PU X/Y cm	Warp/weft steps	Warp/weft um	Use/Find
CHMNYC 1902 1 240	**17 Samite - alternate - multiple main warp - S or Z twill - no twist binding warp**															
	**Subgroup: b**															
	natural	234		0.8	0.8		Z	2	altern	5.4	24.3	0.2	6.0	1	1837	
		Med			Thin grd		1:2		last	Loose		Low warp	6.4	2	822	Badia collection
															0.3	
TMA 11_30	**18 Samite - reverse - single main warp - S twill - design parallel with warp**															
	**Subgroup: a**															
	brown light tan	1982		0.5	0.7		S	2	rever	17.2	31.9	0.5	4.6	1	580	
		Coarse		Thin warp	Thin grd		1:1		first	Med			12.7	2	627	Unknown
															3.2	

Appendix 7.3

Greek Inscribed silks

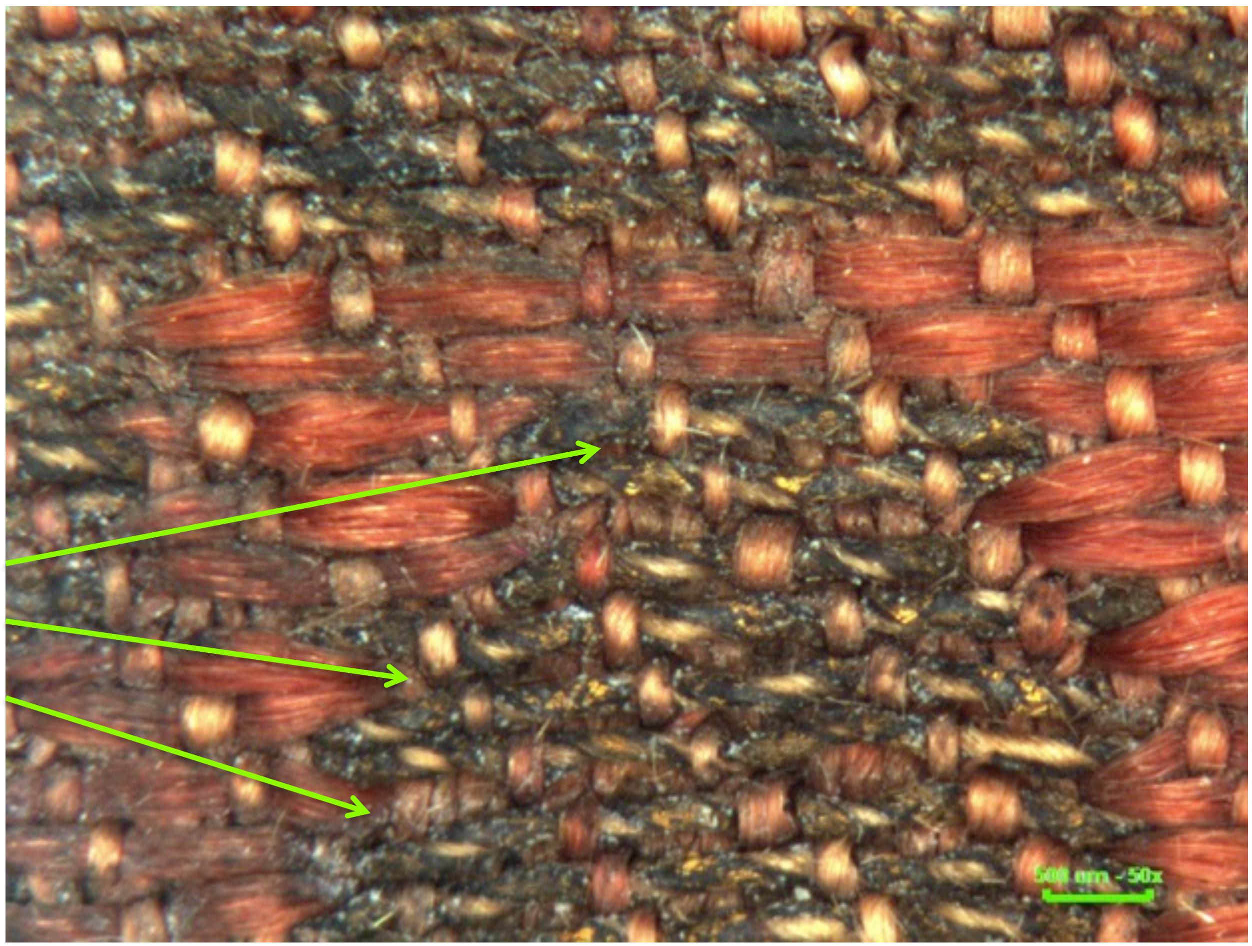
BMAN34973001

DO 165BZ19562

Appendix 7.4

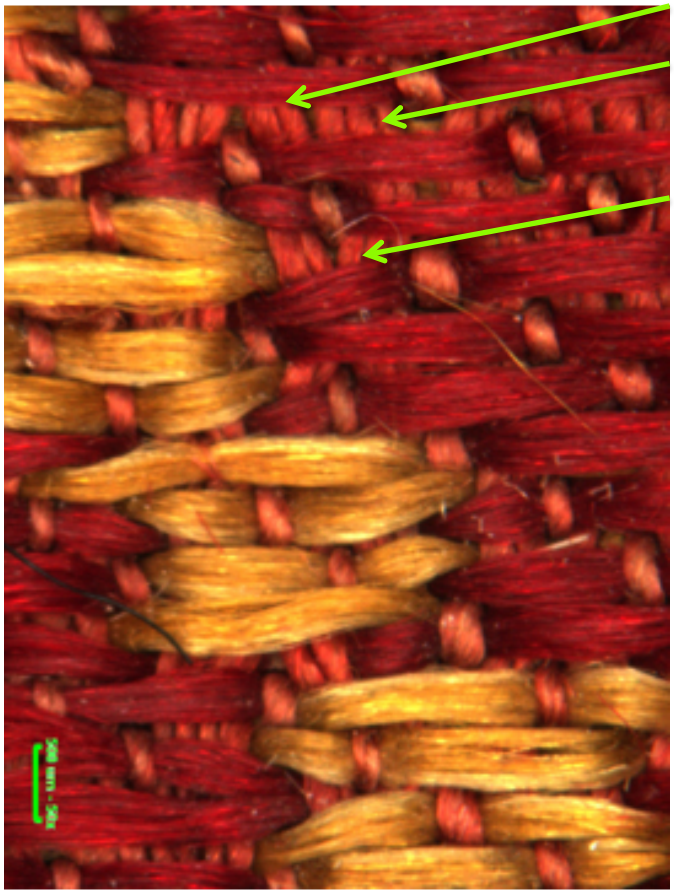
Gold Foil Wrapped Pattern Wefts - CMA 19502_045

Exposed main warps uncovered by gold foil wrapped pattern wefts

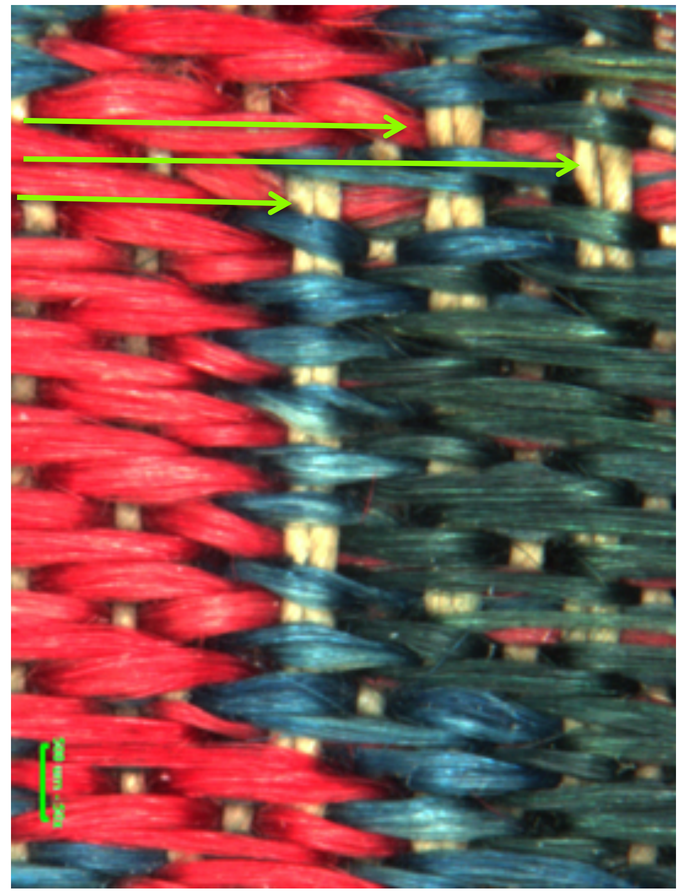


Appendix 7.5

Bare Warps



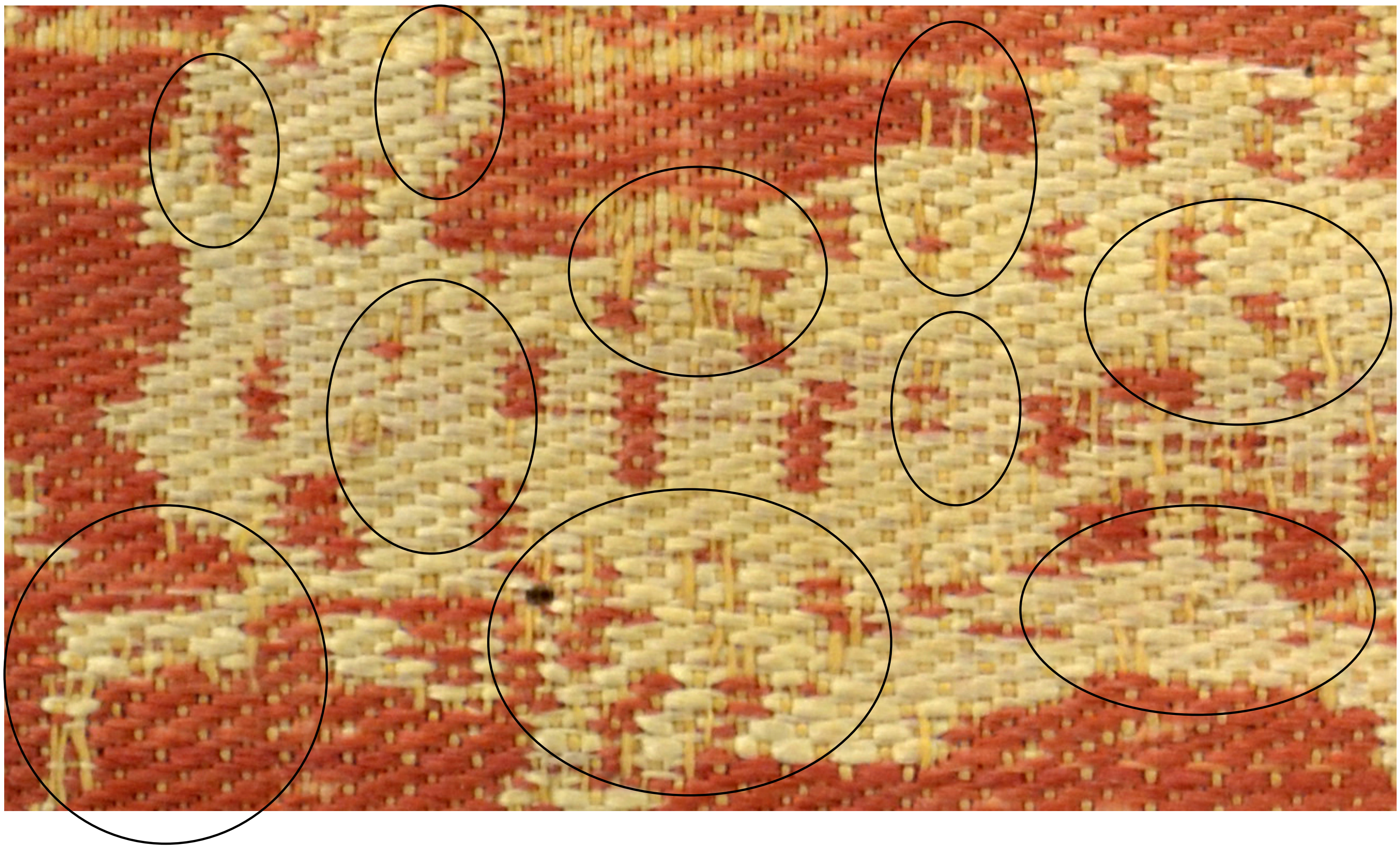
CHMNYC 1902 1 211



CHMNYC 1902 1 214

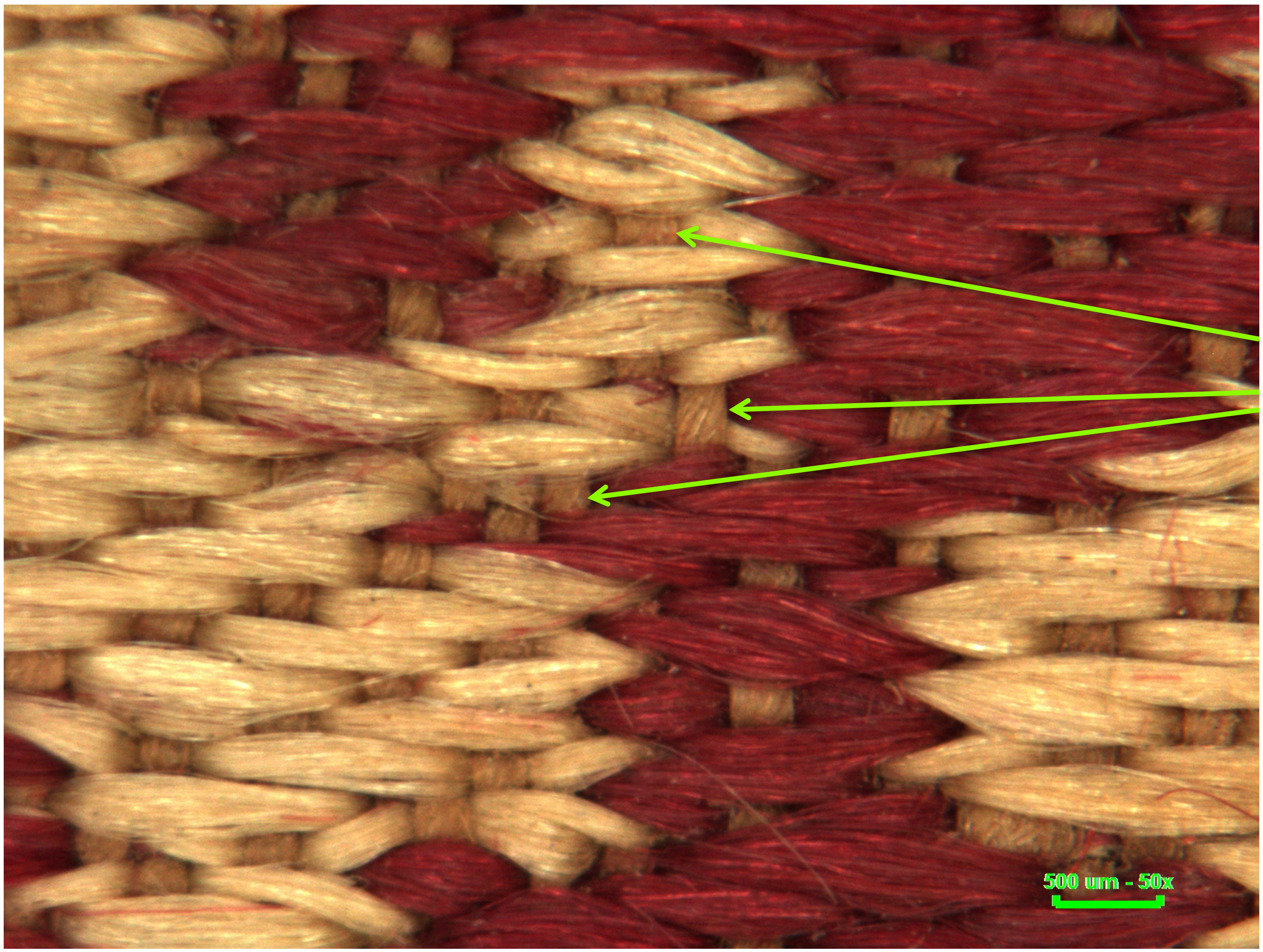
Appendix 7.6

Insufficient Main Warp Tension - DO 168 BZ 1939 32



Appendix 7.7

Work Coordination Problem - DIA 47 75



Incorrect shed sequencing

Appendix 7.8

Effect of Uneven Warp Spacing on Appearance of Figured Images - BMFA 96.35 a,b

Head 1 (frag a)

Head 2 (frag a)

Head 3 (frag a)

Head 6 (frag b)

Head 5 (frag b)

Note: Each image contains 41 warp groups

Dimension comparison

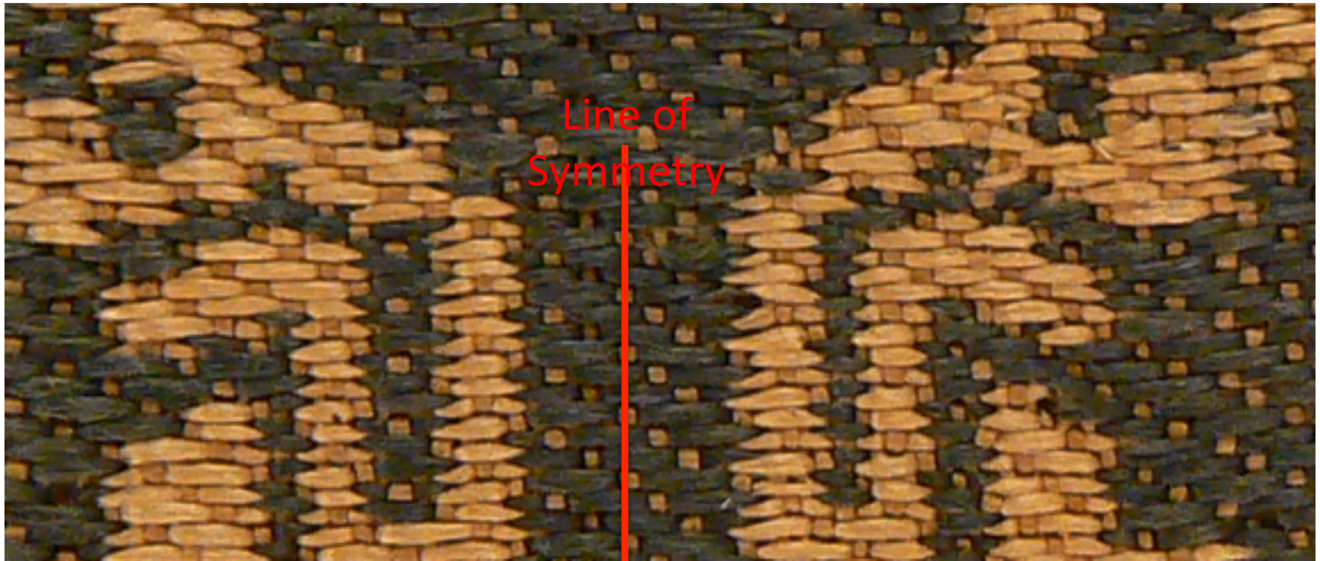
Head No.	Width (mm)	Height (mm)
1	22.5	25.6
2	26.8	27.2
3	34.9	28.3
5	25.3	28.4
6	19.3	29.8

Appendix 7.9

Pattern Tie-up Error - Deformation of Figure on Left - BMFA 33 648

Appendix 7.10

Pattern Warp Tie-up Error Example - DO 169 BZ 1972 10

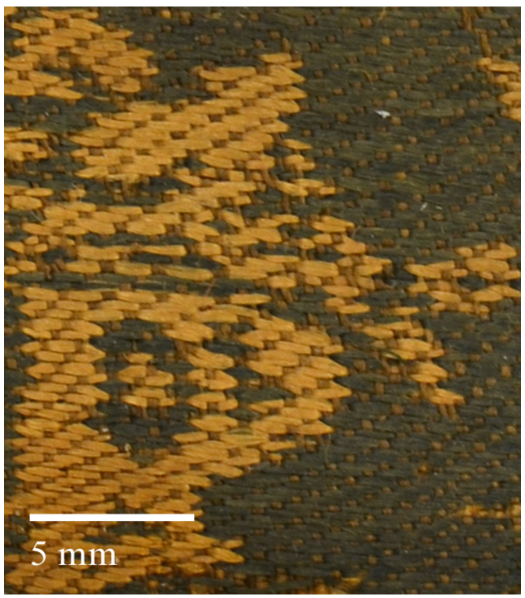


	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	C	B	A	Z	Y	X	W	V	U	T	S	R	Q
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

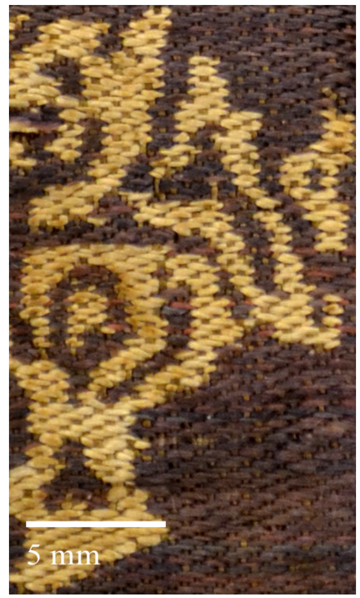
Note: shows the tie-up mistake in pattern warps UVW

Appendix 7.11

Comparison of Horses' Heads Among Related Silks



BMFA 0764a

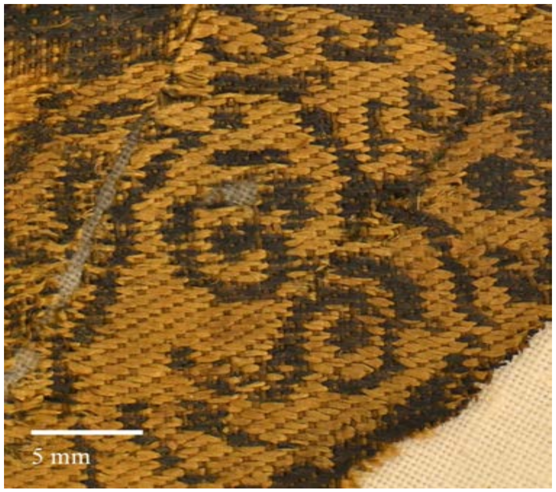


DO 167.BZ.1946.15

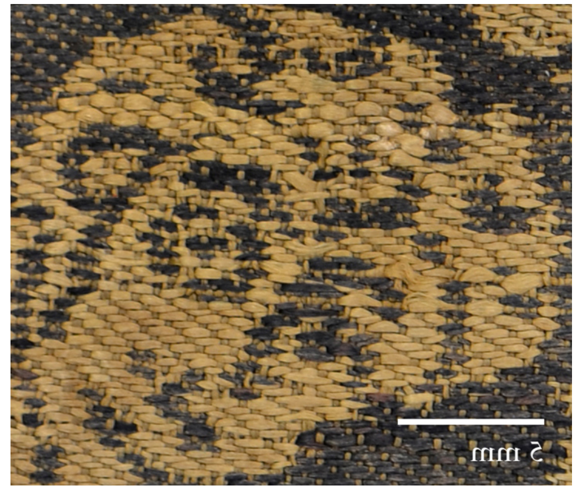
TMA 11.16

Appendix 7.12

Comparison of Amazons' Heads Among Related Silks

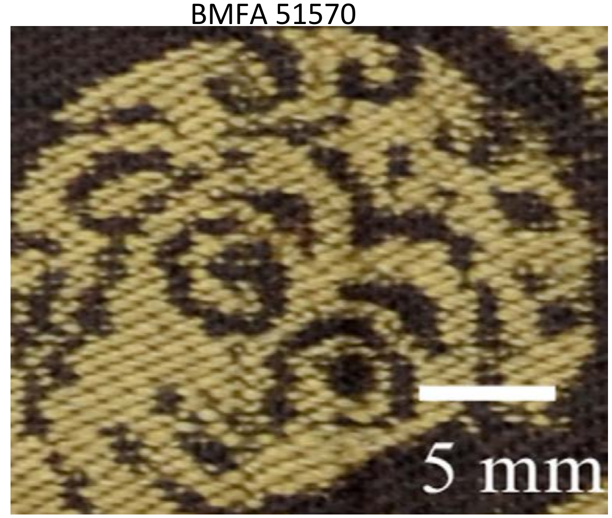


BMFA 0764b



BMFA 51570

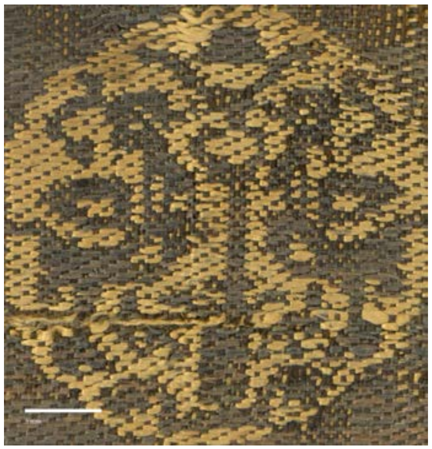
DO 167.BZ.1946.15



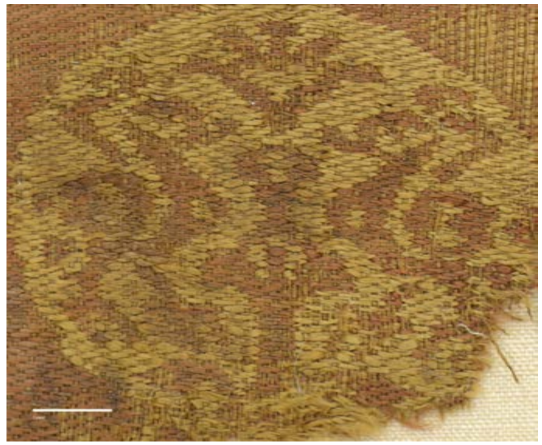
TMA 11.16

Appendix 7.13

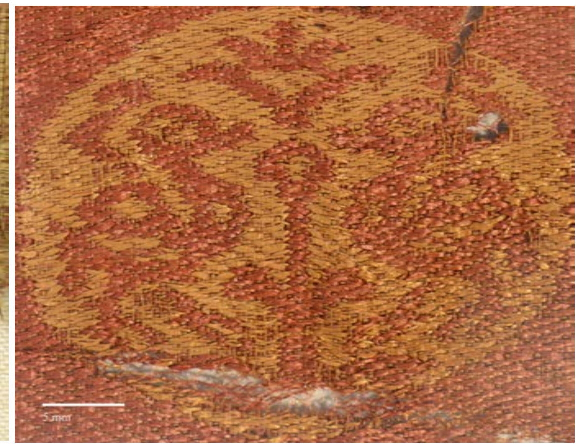
Comparison of Circle Medallion Among ‘Vine Lattice with Birds’ Pattern Related Silks



BMFA 09127008



BMFA 151123009



CMA 1983 139 017

DIA 4775 016 85

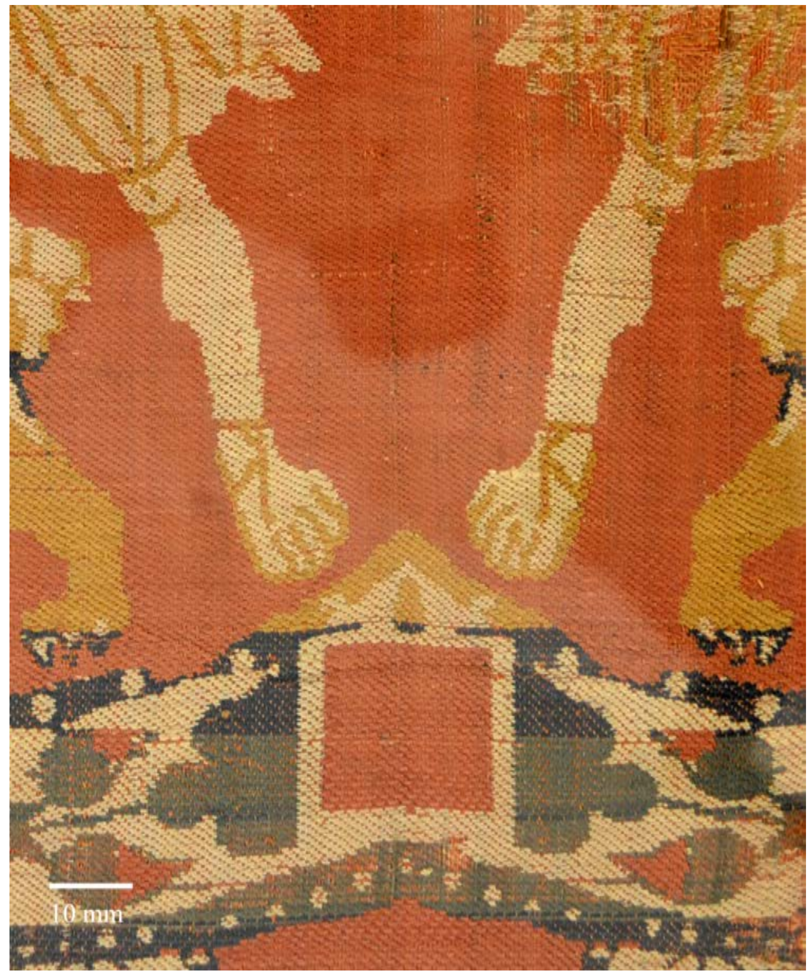
TMA 1121 022

Yale 1939 635 020

Appendix 7.14

Comparison of Pattern Scale and Design for 'Samson' Silks

CMA 1974 97



DO 163 BZ 1934 1