FACULDADE DE CIÊNCIAS SOCIAIS E HUMANAS
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NEW CARPETS FOR NEW MARKETS:

The Production and Consumption of 'Indo-Persian' Carpets, 16th and 17th centuries.

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Doctoral Thesis in History

Area of Specialization History of Discoveries and the Portuguese Expansion

NOVEMBRO, 2016

Doctoral dissertation entitled “NEW CARPETS FOR NEW MARKETS: The Production and Consumption of ‘Indo-Persian’ Carpets, 16th and 17th centuries” presented to conform the necessary requirements for obtaining the PhD degree in History of the Discoveries and the Portuguese Expansion under the scientific supervision of Dr. Jessica Hallett (Centro de História d’Aquém e d’Além-Mar, Faculdade de Ciencias Sociais e Humanas da Universidade Nova de Lisboa, Portugal) and co-supervision of Dr. Blythe McCarthy (Department of Conservation and Scientific Research, Freer | Sackler Galleries of Art, Smithsonian Institution, Washington DC, USA) and Dr. Ana Claro (Centro de História d’Aquém e d’Além-Mar, Faculdade de Ciencias Sociais e Humanas da Universidade Nova de Lisboa, Portugal).

Financial support provided by the Fundação para a Ciência e Tecnologia (FCT), Portugal
PhD grant: *SFRH/BD/72882/2010.*

Aos meus avós,

Domingas, João, Olívia e Virgílio,

As minhas eternas e incondicionais fundações.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to my principal supervisor, Dr. Jessica Hallett, and co-supervisors, Dr. Blythe McCarthy and Dr. Ana Claro, for their guidance and knowledge, without which this work would not have been possible. For their support I am truly grateful. I would like to express my gratitude to all my colleagues and friends at the Department of Conservation and Scientific Research for the their friendship and enthusiasm. My appreciation also extends to all the staff at Freer and Sackler Galleries of Art Library for their good humor and assistance, to Dr. Nancy Micklewright and Zeynep Simavi for providing me with such serene space and my time in the curatorial department so enjoyable. Finally, I would like to express my gratitude to Dr. Julian Raby and Dr. Massumeh Farhad for their time and advice.

My gratitude extends to the Portuguese Science and Technology Foundation (FCT) and the Smithsonian Institution whose support was vital for the development of this project, and to CHAM through which I have received valuable contributions and the opportunity to work with inspiring friends and colleagues. Also, a sincere word to all institutions and individuals that made possible for me to have access to such incredible collections and samples: The Museu Nacional de Arte Antiga (Lisbon, Portugal) and Museu Nacional de Machado de Castro (Coimbra, Portugal), The National Gallery of Art (Washington, DC), the former Corcoran Gallery of Art, The Textile Museum, Dr. Richard Laursen and Dr. Chika Mori, Julia Burke, Esther Méthé, to name a few, many thanks to all of you.

A word to my dearest family and friends (my salt and pepper: Estarolas and Granny's crew), unconditional supporters whose care and support is evenly disseminated throughout each chapter, proving that the Atlantic was never big enough, a big THANK YOU to you all. Finally, my words are to you Giorgio. Indeed carpets brought me in this privileged and unforgettable journey but most importantly, they brought me YOU. I feel grateful for your relentless support, friendship and love, and look forward to write the chapters ahead with you.

NOVOS TAPETES PARA NOVOS MERCADOS:

A Produção e o Consumo de tapetes 'Indo-Persas' nos séculos XVI e XVII.

Ana Raquel Martins dos Santos

A situação do comércio internacional e a estabilidade política do Irão, no século XVI, permitiram reunir as condições necessárias ao desenvolvimento de uma nova fonte económica: a produção e o comércio de têxteis. Os governantes Safávidas viram nesta conjuntura a oportunidade de desenvolver a indústria iraniana de tapetes, respondendo às exigências e competitividade do mercado internacional. Este trabalho desenvolve-se em torno desta transformação, procurando compreender o seu efeito na produção de tapetes persas dos séculos XVI e XVII e determinar como, quando e onde teve lugar, através da colecção de tapetes islâmicos em Portugal e EUA.

A abordagem interdisciplinar adoptada neste estudo recorre a História da Arte, História e Ciências da Conservação, para se focar no estudo do contexto artístico e histórico em torno da sua produção e consumo, assim como na análise estilística, material e técnica, com o apoio da analises químicas, como ferramenta completar para resolver as questões espaciais e temporais da sua produção. Desta forma posiciona o papel do mercado Português e outros mercados Europeus na criação de novos tipos de tapetes para exportação.

A investigação histórica reconhece a complexidade dos contextos políticos, económico e cultural durante os períodos Safávida e Mogol em que se desenvolvem inovações na indústria de tapetes, enquanto o estudo histórico-artístico identificou os desenvolvimentos resultantes da nova tipologia de tapetes através de uma análise sistemática dos 59 tapetes selecionados. A análise técnica e material permitiu aumentar a informação relativa aos processos de produção e, consequentemente, obter resultados mais precisos acerca da sua origem e contexto de produção. O estudo do design dos tapetes e das suas representações em pinturas permitiu traçar a evolução do tipo e desenvolver uma cronologia de produção. Em conjunto os resultados obtidos oferecem uma abordagem nova e abrangente para compreender este problemático grupo de tapetes, permitindo a interpretação do papel do produtor e consumidor durantes os séculos XVI e XVII.

Este trabalho contribui para um melhor conhecimento do impacto de novas redes de comércio no desenvolvimento de uma das maiores formas de expressão artística iraniana e apresenta uma ferramenta para coleções públicas e privadas em todo o mundo que incluem tapetes semelhantes.

PALAVRAS-CHAVE: Expansão Portuguesa, tapetes, Irão, Índia, corantes naturais, fibras naturais, tecelagem, design, têxteis históricos, cromatografia líquida de alta resolução, espectrometria de massa, microscopia óptica, comércio, produção, consumo.

NEW CARPETS FOR NEW MARKETS:

The Production and Consumption of 'Indo-Persian' Carpets, 16th and 17th centuries

Ana Raquel Martins dos Santos

International trade and political stability in 16th-century Iran gave rise to new economic developments, including textile production. The new Safavid rulers saw this moment as the ideal opportunity to develop the Iranian carpet industry to respond to the demands and competitiveness of the international market. This work aimed to look at this transformation during the 16th and 17th centuries, to establish how, when and where it occurred, through the collection of Islamic carpets in Portugal and USA.

The interdisciplinary approach taken in this study involving Art History, History and Conservation Science, focused on the study of the art historical and historical contexts surrounding their production and consumption, as well as a close analysis of stylistic features, decorative materials and technical components, supported by science, as a complementary tool for assessing the spatial and temporal dimensions of their production, while establishing the role played by the Portuguese and other European markets in encouraging the creation of new types of carpets for export.

The historical research recognized the complex political, economic and cultural background during the Safavid and Mughal periods that set the stage for carpet industry innovations, while the art historical identified the subsequent development of the new carpet type through a comprehensive survey of the 59 selected carpets. Technical and material analysis achieved a more detailed understanding of manufacturing processes, thus delivering more accurate results regarding their origin and context of production. The study of carpet designs and their painted depictions allowed to trace the evolution of the type and to develop a chronology for production. Together the results of this combined methodology offer new and broader insights to the understanding of such a problematic type and allowed the interpretation on the role of the producer and consumer between the 16th and 17th centuries.

This study contributes to a better understanding of the impact of the new overseas trade networks in the development of one of the great forms of artistic expression in Iran and presents a tool for public and private institutions worldwide housing similar carpet types.

KEYWORDS: overseas expansion, carpets, Iran, India, natural dyes, natural fibers, weaving, design, historical textiles, high performance liquid chromatography, mass spectrometry, optical microscopy, trade, production, consumption.

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AUTHOR'S NOTE

In this dissertation follows American English orthography as the project was conducted between Portugal and the United States of America. In addition English was chosen to facilitate future access to researchers worldwide.

LIST OF ABBREVIATIONS

MNAA	*Museu Nacional de Arte Antiga*
MNMC	*Museu Nacional de Machado de Castro*
NGA	*National Gallery of Art*
CGA	*Corcoran Galleries of Art*
TM	*The Textile Museum*
LJF-DGPC	*Jose de Figueiredo Laboratory - Direcao Geral do Patrimonio Cultural*
HPLC-MS	*High Performance Liquid Chromatography coupled with Mass Spectrometry*
OM	*Optical Microscopy*
HCA	*Hierarchical Cluster Analysis*
PCA	*Principal Component Analysis*
SEM	*Scanning Electron Microscopy*

Beholding a work of art, we discern a universal message that goes beyond the constraints of space and time. Though they may do so in different ways, science, history, and art thus unitedly express the basic human desire for knowledge and our constant search for universality along the road to progress.

Enrico Ciliberto in "Modern Analytical Methods in Art and Archaeology"

CHAPTER I
HISTORICAL BACKGROUND

Portugal's interest in overseas navigation can be explained by its geographical location on the west coast of the Iberian Peninsula. With the support of the crown, the explorer Bartolomeu Dias (ca. 1450-1500) succeeded in connecting the Atlantic and Indian oceans by sea.[1] Sailing round the western coast of the African continent he travelled as far as the Cape of Good, a route that would later be used in 1498 by Vasco da Gama in his epic voyage to India.[2] As a result of this momentous development, a variety of goods and products circulating in the Indian Ocean began to arrive in Lisbon.

This profitable trade network operated through a wide range of locations, from the Persian Gulf as far east as China. While the trade of perishable goods, such as spices, can only be traced in historical sources or in the occasional shipwreck, other more durable products, such as ivory[3], metalwork[4], ceramics[5], lacquer[6] and even textiles,[7] offer material evidence of this trade. According to Pedro Teixeira, textiles gained increasing prominence in the 17th-century cargoes and Portuguese ships were laden with products from Iran and India.[8] This increasing interest in Asia in Portugal and elsewhere in Europe led to important develops in production in Iran and India.

This chapter begins by looking at the political and economic interactions between Portugal and Iran and India during the 16th and 17th centuries. It aims to assess the commercial importance of textiles in the export trade to Portugal and other European countries, such as the Netherlands, particularly knotted-pile carpets. After looking at the economic interactions that encouraged the development of the carpet industry under the Safavids (1501–1722) and Mughals (1526-1707), it then attempts

1 Arasaratnam, 1995; Arasaratnam, 2004; McPherson, 2004.
2 Castanheda, 1979; Chaudhuri, 1998a, p. 323 ;
3 Curvelo, 2002, pp. 55-59.
4 Allan, 2003, pp. 203-240.
5 Crowe, 2003, pp. 249-256.
6 Curvelo, 2010, pp. 201-215.
7 Karl, 2012, pp. 114-126.
8 Pedro Teixeira, Reis da Persia, 1604: "Three areas of Persia manufactured carpets, which the Portuguese call 'alcatifas' and Persians call 'kalícha'. The richest and finest and most highly esteemed come from Yazd. The second best come from the kingdom of Kirman and the third, from Khurasan. They are made also inAgra, Bengal, and Cambay but not fine ones." in Hallett, 2007c, p. 92.

to clarify the major features of Persian and Indian carpets: firstly, by understanding the origins of the Safavid style, and then by characterizing the Safavid and Mughal productions. Finally, it looks briefly at the response of the Portuguese market to these industries and their artistic production.

I. 1. Portuguese encounters with the Safavid and Mughal empires overseas

In a letter written to Pope Alexander VI (1492-1503) on 25 August 1499, King Manuel (r. 1495-1521) describes himself as: 'Lord of the conquest, navigation, and commerce of Ethiopia, Arabia, Persia and India'.[9] This title summarizes the ambitious political agenda he had for his reign. From ancient times Portugal had commercial and cultural bonds with the Mediterranean[10] and, by 1500, overland contact extended well beyond the region. Pilgrims travelled regularly to Jerusalem, while Portuguese Jews and Christians voyaged to the Middle East and Southeast Asia. Here, they came into contact with the Ottoman, Safavid and Mughal empires (figure I. 1), which were connected by well-established trade routes between Istanbul, Isfahan and Delhi.[11]

In Lisbon, King Manuel had access to echoes of Iranian affairs, and his interest in the territories around the Indian Ocean was very pragmatic: finding a direct sea route to India to secure and consolidate the profitable spice trade in Malabar on the southeast coast of India.[12] The king's ambition grew soon after receiving his first envoy's reports on the Indian Ocean trade. The Portuguese crown strategy for overseas expansion came to pursue ports in Gujarat (India), Oman, Iran and the Persian Gulf.

Long before the Portuguese arrived in 1501, the kingdom of Hormuz exerted considerable control over maritime trade and commercial activities between the Persian Gulf and Arabian Sea, through the Gulf of Oman.[13] There was also vibrant inter-port

9 Cunha, 2011, p. 14.
10 Cunha, 2011, p. 15.
11 "The Ottoman, Safavid and Mughal states are characterized here as Muslim empires because they were ruled by Muslim dynasties, whose individual monarchs embraced Muhammad's revelation and, to varying degrees, observed the tenets of the Islamic faith. They patronized Islamic religious and social institutions, driven by either genuine piety or enlightened self-interest or by differing combinations of these motives" in Dale, 2010, p. 3.
12 Cunha, 2011, p. 16.
13 "In the 10th century, the town of Hormuz was the chief port for Kermān and Sistān, although the main Persian Gulf port was Jannāba. It was known for its cultivation of a variety of millet (*dorra*), indigo, cumin, and sugarcane, while it allegedly supplied all of Persia with dates" in Yarshater, 2004, p. 471.

commerce in many other coastal cities linked to overland trade networks.[14] This conjunction of local and international exchange explains how Hormuz became a significant emporium for a wide range of goods[15], which Pêro da Covilhã recognized as early as 1489.[16] Products sold on the island of Hormuz had numerous origins, as stated by Castanheda (c. 1500-1559):

> "From India, come all the spices, drugs and stones and many cotton clothes, mats and red burnished stones. From Malacca, clove, apple, walnut, sandalwood, camphor, porcelain, beijoim and tin. From Bengal, several fine cotton cloths (…) From Alexandria and Cairo, mercury, vermilion, saffron, copper, rose-water, brocades, taffeta (…) and carpets. From China musk, rhubarb and silk. In return seed-pearls, pearls, Arab and Persian horses, raw silk, twisted sewing silk, dates, raisins, salt, sulphur and many other goods".[17]

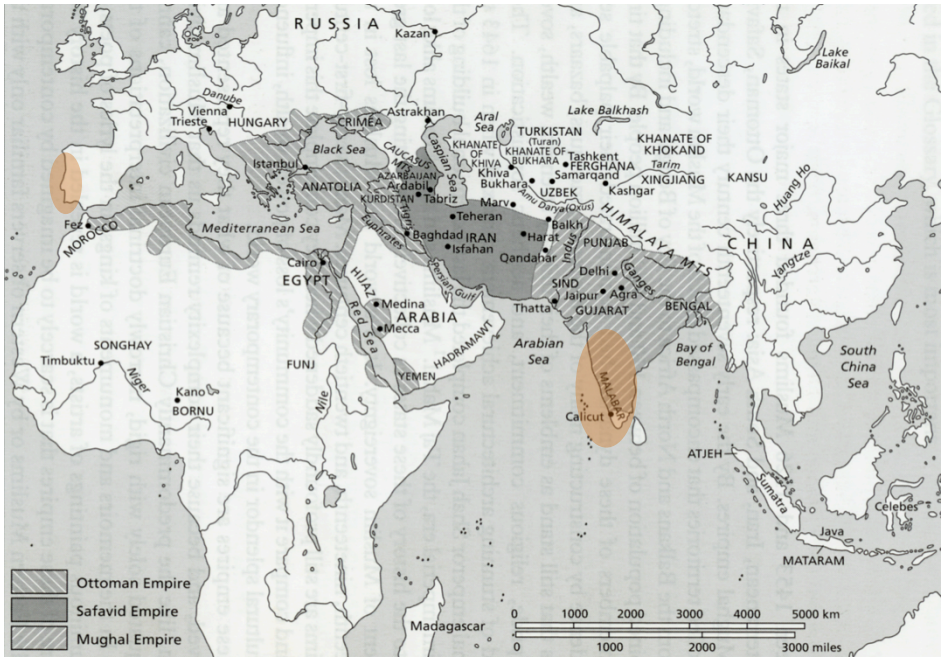

Figure I. 1: Map of the Muslim Empires territory in 1700. Published by Dale, 2010. Portugal and the

14 Floor, Willem; Hakimzadech, Farhad, 2007, p. XII: "Other ports in the Persian Gulf and the Gulf of Oman were of importance for local distribution purposes and included Basra (to supply, Iraq, the Levant and to some extent Khuzestan), Bandel de Camorao (to supply Safavid Persia), Rishahr (to supply part of south Fars), Muscat (to supply Oman) and Qatif (to supply Arabia, mainly Hasa)".

15 Luz, 1960, fl. 32v.: "*A circulação de Mercadorias no golfo Pérsico passava em grande medida pela ilha de Ormuz, considerada, ´o mais célebre empório e escala do mundo´, com ´maior concurso e trato de todalas mercadorias orientais e ocidentais, (…)*".

16 *Dicionário da História dos Descobrimentos Portugueses*, 1994, vol. II, p. 893; quoting João de Barros, década II, liv. II, cap. 2: " a cidade é tam viçosa e abastada, que dizem os moradores della que o mundo é hum anel e Ormuz hũa pedra preciosa engastada nelle". "The city is so rich and full of life, that the inhabitants say that the world is a ring and Hormuz his precious stone".

17 Castanheda, 1979: liv. II, cap. LIX, p. 340; quoted by Magalhães, Joaquim R., 1998, "Articulações inter-regionais e economias-mundo", in *História da Expansão Portuguesa***,** vol. I, p. *326.*

Malabar coast.

Hence, Hormuz was a center for trade in luxury and high quality products that attracted an international clientele, promoting wealth and prosperity in the Persian Gulf and was "the main income of Persian rulers".[18] This potential caught Afonso de Albuquerque's (c. 1453-1515) attention whose strategic skills for overseas conquests was already recognized. Controlling Hormuz became part of Albuquerque's military strategy as he saw it as a potential settlement to extend the Portuguese overseas empire. After successful incursions into several Arab cities on the East African coast, Albuquerque reached Hormuz immediately after taking control of Malabar (1611), where the main spice routes converged.[19]

Albuquerque's first attempts to found a fortress on the island of Hormuz in 1507 and 1508 failed. Nevertheless, he was still able to establish the first contacts between Portuguese authorities and the Safavid Shah Ismail I (r. 1487-1524).[20] Accordingly, as Cunha explains in a letter to Viceroy D. Francisco de Almeida (1505-1509), Albuquerque mentioned that what struck him most about the Safavids was a new form of Islam and the red cap worn by members of the Qizil-Bash[21], along with their swift conquest of Iran.[22]

Around 1510, Portuguese perception of Iran shifted as a consequence of Albuquerque's conquest of Goa (see Appendix B, figure 1). In that same year, and after being nominated as Goa's governor, Albuquerque met with two Safavid ambassadors dispatched to the Bijapuri court. They provided him with information about the shah's

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18 *Das relações entre Portugal e a Pérsia 1500-1758*, 1972, p. 261; quoting *Relaçao de huma carta que Elrey da Persia mandou a Elrey Catholico de Espanha.* Lisboa: Na Officin. De Domingos Gonsalves, Anno MDCCLXVII (BNL: L. 3559 A).

19 Smith, 1970, p. 9. Dicionario da historia dos descobrimentos portugueses, 1994, Vol. II, p.833.

20 *During the first voyage of Afonso de Albuquerque to Ormuz the Portuguese commenced to have relations with the Kingdom of Shah Ismael I (1502-1524). In the days after Afonso de Albuquerque forced the king of Ormuz, and his first minister, Coge Atar, to agree to pay King Manuel of Portugal fifteen thousand xarafins of gold in tribute each year, (…) he received the word of Coge Atar, that, (…) two ambassadors of the king of Xiraz (Shiraz) had arrived asking for the tribute (…). Coge Atar desired to know what reply to return to the ambassadors"* by Smith, Ronald B, 1970, *The first age of the Portuguese embassies, navigations and peregrinations in Persia (1507-1524),* p. 10.

21 "In its general sense, the word is used loosely to denote a wide variety of extremist Shi'i sects (…). The common characteristic was the wearing of a headgear. In its specific sense, the word was a term of opprobrium applied by the Ottoman Turks to the supporters of the Safawid house, and adopted by the latter as a mark of pride. In the Safawid state, established in 1501, the Qizil-Bah constituted the military aristocracy, for they had been largely responsible for bringing the Safawids to power (…)" in Donzel, 1994, p. 361.

22 Cunha, 2011, p. 16.

political orientation in relation to Portugal's two major enemies: the Egyptian Mamluks and the Ottomans. In a letter, Albuquerque reported this encounter to King Manuel and outlined the advantages of establishing a political alliance with Shah Ismail I. He sent the letter, together with gifts from Mir Abu Ishaq, one of the ambassadors, to the king.[23]

Later, in 1515, Albuquerque became concerned at the prospect of losing Hormuz to the Safavids and returned to the island.[24] It was only in 1515, however, that the Portuguese settled officially in the Persian Gulf by taking power from the royal-house of Hormuz (figure I. 2).[25] These were the first steps towards creating what would become one of the most important Portuguese settlements in Iran.[26]

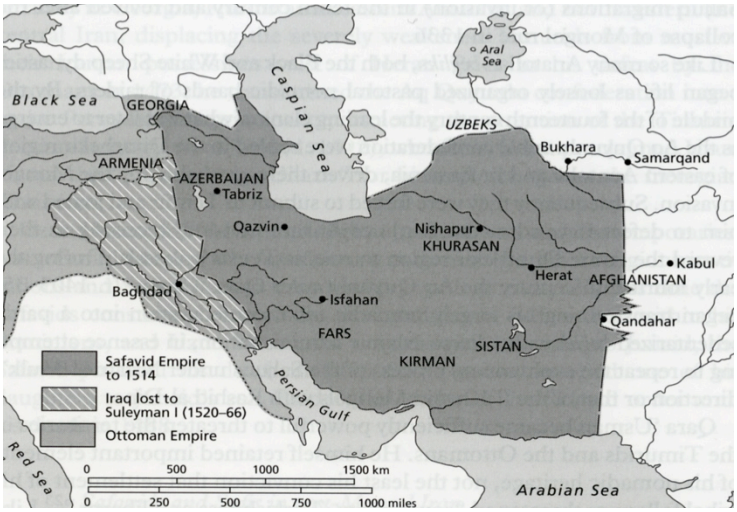

Figure I. 2: Map of the Safavid Empire to 1514 and the location Hormuz in the Persian Gulf. Published by Dale, 2010.

Afonso de Albuquerque tried to consolidate the commerce of the Portuguese empire by promoting the trade of spices and luxury items in Hormuz and Indian ports. Arab horses and textiles were among the goods that suited the taste and demands of consumers from Europe, India and the Middle East.[27] The nature of commerce in the

23 Cunha, 2011, p. 17.

24 Floor, Willem; Hakimzadech, Farhad, 2007, "The Hispano-Portuguese empire and its contacts with Safavid persia, the kingdom of homuz and Yarubid Oman – a bibliography of printed publications 1508-2007", in *Acta iranica*, 43, p. XIII.

25 In *Revisiting Hormuz: Portuguese interactions in the Persian Gulf region in the early modern period*, 2007, p. ix.

26 Couto;Loureiro, 2008, p. ix.

27 Moreira; Curvelo, 1998, vol. II, p. 502: "the organization and horse commerce between Middle East and India was a particular branch of business where Portuguese merchants specialized through which they were providing Indian armys"; Chaudhuri, 1998a, p. 194: "Portuguese specialized themselves in

Persian Gulf was regional and reflected the multicultural environment, and this may in part explain the rapid acceptance of the Portuguese within the trading system. Relations between Portugal and Iran are documented by many contacts and diplomatic embassies during the Safavid period.[28] The encouragement of these relations was mainly due to mutual interest in uniting their efforts against common enemies, particularly the Ottomans.[29]

Political and economic instability on the Iranian mainland did not represent any significant threat to the Portuguese. Instead, together with the Malabar Coast and Goa, and the consolidation of the main sea routes of the *Estado da Índia,* the volume of trade increased, and the Portuguese became a major player in the Indian Ocean trade during the 16th and 17th centuries. Portuguese commercial activities were mainly distributed between three geographical areas: the Persian Gulf; the Red Sea and western coast of Africa; and the eastern coast of India.[30] Within this network of maritime connections, Lisbon became a new link for direct, unmediated transfers of spices with Western Europe. As result, in 1580, Lisbon joined Venice and Seville to become a significant European capital in a worldwide exchange system that included Europe, Asia, Africa and the Americas.[31]

Albuquerque targeted the growth of trade by fulfilling demanding tastes and patterns of consumption of "exotic" quality products to markets in Europe, the West and South Asia.[32] Despite the incomplete information on the contents of exported cargoes, it is possible to determine that pepper, ginger, cinnamon, cloves, nutmeg, mace, aromatic gums and resins, cotton textiles, indigo and raw silk were among the

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cotton textiles from India throughout the Indian Ocean"; Magalhães, 1998a, vol. I, p. 329: "Clothes from Bengal worth a lot in Malaca as all the East appreciates them".

28 *Dicionário da História dos Descobrimentos Portugueses*, 1994, vol. II, p. 890: "D. Duarte Meneses, sends Baltazar Pessoa, together with António Tenreiro, to lead the embassy direct to Persian court in September of 1523. (…) In 1549, Indian governor, Jorge Cabral, sends Henrique de Macedo as an ambassador to met Shah Tahmasp I".

29 The Portuguese firepower embodied an enormous advantage against the Turks and in later years Filipe II promised to provide Abbas with weapons. For further details please see: Carswell, 1968, p. 106.

30 Chaudhuri, Kirti, 1998, "O comércio asiático"*,* in *História da Expansão Portuguesa,* vol. I, p. 200.

31 Chaudhuri, 1998a, p. 248.

32 *A roupa de Bengala vale muito em Malaca porque é mais valia em todo o Levante* by Magalhães, Joaquim R., 1998, "Articulações inter-regionais e economias-mundo", in *História da Expansão Portuguesa***,** vol. I, p. 329.

most popular goods from the Persian Gulf.[33] The rewarding outcome of this trade soon led to the island of Hormuz being recognized as "(…) the Portuguese Kings' most important settlement in the Indias (...)".[34]

Not surprisingly, the Safavids also had interests in the Persian Gulf, but until the rule of Shah 'Abbas I (r. 1587-1629) these were mostly of a tributary nature. Throughout and even after the Safavid period, Iranian rulers' natural affinity and primary interests were centered on the mainland interior, where their principal resource base and main enemies were found.[35]

Albuquerque's commercial endeavors in the Persian Gulf resulted in Portuguese control of the luxury trade in Hormuz for over century. Inherently, the Portuguese contribution to the expansion of these economic encounters, whether by maritime trade system or gift exchanges, is testified by literature, through travel accounts, diplomatic embassies and royal inventories, [36] and by decorative art objects, particularly textiles.[37]

I. 2. Textile Industries and Trade

The establishment of the overseas route from Europe to India in 1498 not only strengthened maritime trade, but also confirmed that European technology lagged behind that of the Middle East, India, China and Japan, particularly in textile dyeing

33 *As informações sobre a composição exacta das cargas dos navios não estão completas, mas temos uma ideia geral a respeito da natureza dos bens (…). No regresso, a carga era composta por pimenta-negra, gengibre, canela, cravinho, noz-moscada, macis, gomas aromáticas e resinas, têxteis de algodão, índigo e sedas em bruto* by Ibidem, p.196.

34 *Das relações entre Portugal e a Pérsia,* 1972, p. 231.

35 Matthee, 2011, p. 219.

36 *Através do enorme acervo da literatura de viagem e das cartas-missivas vindas do Oriente, deparamo-nos a cada passo com menções a presentes enviados para a corte. (…) Não se tratava de um acto isolado, mas de prática corrente entre soberanos* by Moreira, Rafael; Curvelo, Alexandra, 1998, "A circulação das formas – Artes portáteis, arquitectura e urbanismo", in *História da Expansão Portuguesa***,** vol. II, p. *535.*

37 "Although the word "textile" was originally used to define a woven fabric and the processes involved in weaving, over the years the term has taken on broad connotations, including the following: (1) staple fibers and filaments for use in yarn or preparation of woven, knitted, tufted, or nonwoven fabrics, (2) yarns made from natural or man-made fibers, (3) fabrics and other products made from fibers or from yarns, and (4) apparel or other articles fabricated from the above which retain the flexibility and drape of the original fabrics. This broad definition will generally cover all of the produced by the textile industry intended for intermediate structures of final products" in Needles, 1981, p. 1-2*;* The term *textiles* here should be read as follows: *textiles is the generic term used by commodity to designate a large variety of objects made of woven fabric or embroidered (…).* Such definition can be found in Moreira, R. and Curvelo, A., 1998, p. 546.

and weaving.[38] Not surprisingly, therefore, cotton fabrics, woolens, and silks were among the most profitable goods in world trade.[39]

In the 16th century, direct commerce between West, South and East Asia and Europe represented only part of the vast and complex economic trade system ongoing in these regions.[40] To participate in this new system, European markets had to adapt their commercial methods to the patterns of trade between different harbors in the Indian Ocean. From September to January, dealers from the Red Sea would acquire cotton fabrics from manufacturing cities and villages in Gujarat. Merchant cargoes would leave ports like Cambay, Diu and Surrat to be sold in Ormuz, Mascat, Aden and Jedda markets.[41] Similarly, the Portuguese greatly appreciated Indian textiles made of cotton; thus taking an active interest in this trade in the Indian Ocean. In the first decades of the 17th century, therefore, cotton textiles from India were imported via the Cape of Good Hope by Portuguese ships. Their cargoes aimed to match the necessities of new consumers to whom these new textile commodities were highly appealing.

The consumption patterns in European markets followed closely the appeal for these new textiles, which would change significantly over the course of 16th and 17th centuries.[42] According to some authors, carpets were among the most highly sought-after objects ordered by the Portuguese from Indian artists.[43] However, the excellence of Iranian knotted-pile carpets had already been recognized during the first encounters between the Portuguese and the Safavids in the 16th century.[44]

The Safavid period (1501-1722) is renowned as the golden age of textile weaving in Iran. During this time a variety of silk textiles, velvets, metal thread textiles, *tirma* (plain cloth), *qalamkār* (printed, painted and dyed cottons) and a variety of tapestry-woven textiles were produced in different workshops in the cities of Isfahan,

38 Chaudhuri, 1998c, p. 493.
39 Chaudhuri, 1998b, p. 267.
40 Chaudhuri, 1998a, p. 323; Floor, 2012, p. 207.
41 Chaudhuri, 1998b, p. 265.
42 Moreira, R. and Curvelo, A. 1998. pp. 546.
43 "(…) alcatifas de estrado, tapetes – contam-se entre os objectos encomendados em maior número a artistas indianos" in Moreira, R. and Curvelo, A. 1998. p. 546.
44 "Portugueses e outros observadores anotaram e comentaram a excelência dos tapetes iranianos, (…)" in Chaudhuri, 1998c, p. 493.

Yazd, Kashan, Herat, Mashhad, Rasht, Qum and Sava, among others.[45] Each of these centers was famous for producing specific types of textiles, including knotted-pile carpets, long valued for their texture, warmth and appealing colors and patterns.

Iranian carpets became more accessible to wealthy European consumers in the early 17th century, with Shah 'Abbas I's active interest in developing trade with European countries. Their popularity also increased the competitiveness of the Iranian carpet industry in relation to the Ottoman one that, with the production of wool carpets, had dominated the carpet trade with Europe, by way of Italian ports and Mediterranan trading networks during the 15th century.[46] Consequently, with the rise of the sea route to India, the Portuguese market, in particular, benefited from direct access to Iranian knotted-pile carpets, which were recognized for their fine quality and materials. To fully comprehend the value and prestige of these objects, however, it is necessary to understand their laborious manufacture.

I. 3. Safavid and Mughal carpet production

The 16th-century Iranian economy, like centuries before, was in part based on the production and trade of high quality textiles.[47] During the Timurid period (1389-1508) gold weaving continued at centers such as Tabriz, Kashan and Herat. With Safavid royal patronage of gold weaving and weavers, especially under Shah Abbas I (r. 1587-1629), many beautiful pieces were produced. Luxurious velvets, lampas[48] and carpets of silk and gold weaving became one of the special arts of the Safavid period (1501-1722).[49]

Court artists developed designs in a variety of media. Together with ceramics,

45 Ruhfar, 2002, p. 83;

46 "In Turkey there was a vigourous domestic tradition even in the fifteenth century. Carpets evidently made in cottage industries were being exported to Europe at this time, as paintings of the period reveal. Against this background a flamboyant new court style developed during the second half of the sixteenth century. Large curving feathery leaves, palmettes, rosettes and tracery are combined inton a graceful swirling pattern. Tulips, hyacinths and carnations were added later*"* in Thompson, 1993, p. 150.

47 *Das relações entre Portugal e a Pérsia 1500-1758*, 1972, p. 30; citando Carta de D. Manuel I ao bispo de Segóvia, D. Fradique, Lisboa, 12 de Julho de 1511, Documentos II, p. 232, Cartas, III, p. 20-1, Carta III, p. 5-6, (CC. I-10-60): "Sending to D. Manuel I the gift brought by Goa's 'king' ambassador's; gift description: horse saddle and blankets, very richly decorated with gold and silk embroideries, and silk fabrics popular in that area, and many rich hats and other things and a red hats, with a tall sort of turban".

48 Term is introduced as " integrated weave structures" by Emery, 1995, p.159-160 as follows: "When structures of two complete weaves are integrated, that it, completely interwoven, in one fabric, each set of warps has a companion weft set with which it interweaves in a regular weave order.

49 Ruhfar, 2002, p. 83; Bier, 1987, p. 57.

calligraphy, paintings, woodwork, and metalwork, carpets were part of the corpus of royal arts produced under Safavid patronage. By contrast, in India, carpet manufacture was not a long-lived tradition. The first court carpets were made in the second half of the 16th century by Persian craftsmen brought to the Mughal court.[50]

Around 1549, the exile Mughal ruler Humāyūn returned to India with two of Shah Tahmap's finest artists Mir Sayyid Ali and Abd al-Samad, who worked with Hindu and Muslim painters to establish the Mughal School of painting.[51] In the 17th century, a distinctive Mughal style of high technical and artistic quality emerged. It included magnificent carpets displaying lattice and flowering designs.

Production costs were greatly affected by the materials, colors, weaving techniques and designs. As a result only the wealthiest workshops had access to the high quality materials, craftsmanship and sophisticated designs necessary to produce the finest works. It is possible that urban workshops, which enjoyed the patronage of the court and the ruling elite, had the necessary resources to produce objects of fine quality and with the most sumptuous designs. This textile-based economy, however, was in prominent danger with the persistent threats of invasion, volatile political and religious circumstances and the sizeable territorial dimensions were the main difficulties to controlling and protecting lands under Safavid and Mughal domination.[52]

I. 3. 1. Safavid production

The conquest of the cities of Tabriz (1501) and Herat (1507), particularly, had a tremendous impact on the arts of the Safavid Empire. For much of the 15th century, two predominant and distinct artistic styles existed; one flourished at the Timurid courts in the east, mainly in Herat, and the

Figure I. 3: Map of the Safavid Empire in 1629. Published by Dale, 2010.

[50] Thompson, 1993, p. 152.
51 Walker, 1997, p. 3.
52 Robinson, 1989, pp. 99-106; Savory, 1986, pp. 394-395; Subrahmanyam, 2012, pp. 104-127; Dahmardeh, 2012, pp. 132-144.

other within the Turkman domain in the west, centered at Tabriz. With the defeat of the two dynasties, Tabrizi and Herati work for the same patrons. This resulted in the fusion of the Timurid and Turkman styles, which laid the foundation of for the Safavid style, which flourished in the 16th and 17th centuries.

The Timurid style seen in paintings and book bindings was based on designs with strong relations between symmetrical framing devices, with overlapping leaves and floral motifs. This style was defined by very fine brush strokes and complex compositions, which were developed at the Tabriz court workshop, the main center of artistic production at this time.

Figure I. 4: Detached frontispiece from a dispersed copy of the Khamsa (Quintet) by Amir Khusraw Dihlavi. Iran, Tabriz, 17th century), Safavid period, ca. 1530-1540. [F|S Galleries collection, Smithsonian Institution]. S1986.67.1

At the end of the 15th century, the Timurid style was distinguished by small scale and dense floral forms, which can be seen in the arts of the book (figure I. 4).[53] Meanwhile, to the west, at Herat, a more regional style with brighter colors and geometrical shapes became popular. The Turkman artists developed more carefully drawn works with varied patterns, which did not enjoy the same appeal on international markets as the Timurid style.

The new Safavid style drew from both artistic traditions and was initially characterized by very detailed work with decoration based on human and animal figures surrounded by filler elements, along with Chinese clouds and several vine scroll layers. In addition, these vegetal and floral motifs were incorporated into geometrical framing devices such as elliptical and star medallions, polilobed and quatrefoil cartouches. This type of decoration was displayed in various art forms such as architecture, bookbinding, and carpets (figures I. 5, I. 6 and I. 7).

53 Canby, 2003, p. 19.

The first ruler whose legacy left a mark on the arts for future Safavid generations was Shah Ismail I (r. 1501–24). His interest in the arts, especially poetry, turned him into a significant sponsor of the arts of the book. Art forms from his time reflect activities, such as hunting and polo, connected to his itinerant life style. This taste is also found in other forms of art such as carpets or bookbinding, although some authors question whether Ismails life and accomplishments can truly be regarded as factors in the development of what became recognized as the Safavid style.[54]

Figure I. 5: Bookbinding cover. Iran, 17th century. Detail of an arabesque split-leaf scroll, with winding tendrils [F|S Galleries collection, Smithsonian Institution]. S1986.13. Published by Santos, 2010.

Figure I. 6: ´Salting' prayer carpet (Iran, 17th century), in wool, silk and metal-wrapped thread. Detail of an arabesque split-leaf, with winding tendrils [Private collection]. Published by Santos, 2010.

Figure I. 7: Ceramic tiles on the exterior of the Shrine of Shaykh Safi, Ardabil. Detail of an arabesque split-leaf, with winding tendrils [Shrine of Shaykh Safi, Ardabil]. Musee du Louvre

Later, Ismail's son and successor, Shah Tahmasp (r. 1524–76), also became a strong supporter of the arts. Shah Tahmasp dedicated much of his life to sponsoring and encouraging the exchange of ideas between artists from Tabriz and Herat. The best artists not only worked for the court but also travelled with the shah. This enabled him to be in close proximity to painters, ensuring that their creations reflected his taste and would be shared with other court artisans working in different media.

54 Idem, p. 6.

The quality of the motifs displayed in a diverse range of art forms suggests that many of these designs were most likely created in court ateliers.[55] This is especially apparent in the arts of the book and in commissions Tahmasp made of sumptuous carpets.[56] The unmistakable quality of the carpets produced at this time is seen not only in their technical features but also in the materials used, which had a great impact on the final result. Instead of cotton or wool for the foundation, silk threads, which were finer and more resistant, were introduced into the pile and foundation, increasing the knot density and thus the detail of the decorative motifs.

At times when enemies were constantly threatening the very shape of the empire, the visual unity created by Tahmasp in the arts represented more than simply an aesthetic choice and sent a clear and intimidating message of Safavid power. Nevertheless, the constant warfare with the Ottoman Empire and loss of large amounts of land in the first half of the 16th century, including Tabriz, the capital and largest city in Iran, led Tahmasp to shift the capital of the empire to Qazvin in 1555.

Tabriz continued to serve as the commercial capital and where, as stated by Thompson, "carpets with the medallion design probably continued to be woven".[57]. Manuscript painters were brought to court workshop in Qazvin, while carpets of outstanding design and materials were also produced in the city of Kashan. One believed example of such is the so-called 'Hunting carpet' in Boston made of silk pile and foundation and embellished with metal-wrapped patterning (figure I. 8).

55 Canby, 2003, p. 13: "Historical texts mention calligraphers who supplied inscriptions for buildings as well as books, bookmakers who were illuminators and painters, and textile designers who travelled in court circles but produced their textiles in Yazd".

56 Canby, 2009b, p. 19.

57 "They have centralised design consisting of a more or less circular medallion of lobed or crenelated outline placed on a field covered with an endlessly repeating design of branched tracery. The medallion design was the great contribution made by Persia to the world of carpets. It is perhaps best known in the famous Ardebil carpet in Victoria and Albert Museum, London." in Thompson, 1993, p. 152.

Figure I. 8: 'Hunting carpet', Iran, 16th century. Boston MA, Museum of Fine Arts Boston, no. 66.293.

However, later in his life, Tahmasp's interest in the arts faded, as he became a devout Shiite, renouncing most pleasures of life, spending his last years secluded in the palace. This development meant a shift in royal patronage and decentralization of artistic support as artists joined other workshops throughout Iran or migrated to the Ottoman or Mughal empires. With the succession of Shah Abbas I, the royal court, once again, took on a central role in the patronage of the arts.

Abbas's legacy reveals a growing concern for using the arts to project and express the wealth and grandeur of the Safavid Empire. As a result, a new vocabulary was created under his reign in which human and animal figures were replaced by floral motifs in a more expanded scale. This new aesthetic was applied to a wide range of media, and lead to the creation of a homogeneous royal style, which was fully affirmed in 1598 when the capital Qazvin was transferred to Isfahan.[58] Shah Abbas' new aesthetic program was visible in the luxury textiles made for export, in which flower motifs with a new colour palette and larger scale were displayed.

58 "There was a lustrum of relative peace which gave Shah Abbas the opportunity to begin the adornment of his new capital" in Canby, 2009a, p. 20.

17th-century Iranian carpet industry: new developments

Aware of the high demand of international markets for textiles, Abbas, a weaver himself, promoted the luxury silk trade to increase the competitiveness of the Safavid industries – including carpet production – especially in relation to Ottoman production as confirmed by previous studies: "So Shah Abbas hoped to involve the European powers in Persian affairs both as trading partners and as potential allies against the Turks by diverting the current of the silk trade from the Levant to the Persian ports at the southern end of the Persian Gulf, particularly Bander 'Abbās [port city in the Persian Gulf].[59] The desire to develop the Iranian carpet industry led Abbas to create a carpet workshop for carpets 'of silk and gold'.[60] These works were used as instruments of diplomacy and sent as royal gifts to local and foreign rulers. The small kingdom of Hormuz, which had been under Portuguese control since 1515, represented an important entrepôt for the export of luxurious products such as silk and textiles.

Indeed, despite the local revolts (1521-22) and naval attacks by the Ottomans in 1552 and 1581, Hormuz continued to prosper under Portuguese rule.[61] By 1617 D. García de Silva y Figueroa (1550-1224), ambassador for the Iberian crowns of Filipe III of Spain and II of Portugal, estimated the number of household at 2.500 to 3000, of which 200 were Portuguese.[62] The lucrative trade through Hormuz caught Shah Abbas's attention. The strong-willed Abbas could not tolerate the Portuguese assets and profits in what he considered to be Persian territory, particularly during his plan to unite the Safavid Empire. As a result, he reclaimed control of Bahrain and Gamru (Gombron) in 1622, the last Portuguese footholds on Iran's mainland. With the naval assistance of the English East India Company, he also took Hormuz.[63]

During the 17th century, through merchants operating in the established Indian Ocean routes, Abbas had privileged and direct access to new European and Asian

[59] "(…) the force settlement of a large number of Armenians in the Persian capital, Isfahan, by Shah 'Abbas I (1587-1629) from 1604, which was decisive for their fortunes in Persia. (…) Those in Isfahan [Armenians] prospered and eventually became powerful, even an indispensable, factor in Persian economic life in the seventeenth century. By assisting the Armenians merchants Shah 'Abbas expected to increase his own revenue from silk trade and reduce the benefits to the Turkish treasury from transit dues and customs" in Ferrier, 1973, p. 38; Ferreira, 2011.

60 Canby, 2009a, p. 79.

61 Yarshater, 2004, pp. 473-474;

62 Yarshater, 2004, pp. 473-474; Ferreira, 2011, p. 1.

63 Cunha, 1995; Yarshater, 2004, pp. 473.

markets. The Iranian carpet industry decreased its costs, while also maintaining reasonable quality and its dimensions to appeal to external markets. Background motifs used earlier were reinvented on a larger scale and given more prominence, in carpet design. Thus, the creation of a new carpet type woven using more affordable materials (cotton warps and wefts instead of silk) in court ateliers and/or in commercial workshops across the territory arose as a highly feasible solution.

Moreover, cities like Tabriz, Kashan, Isfahan, Yazd and Kirman, where carpet production was active, could provide the means for traditional motifs of the Iranian artistic vocabulary to be prepared and reinterpreted by painters into sophisticated compositions of endless variations before being delivered to carpet weavers. Certainly, "the revolutionary nature of these new floral designs and their sheer beauty made them highly-prized imports"[64], features that seem to fit the 'Indo-Persian' carpet type. In addition, reports state that Persian weavers were being brought to the Mughal Court.

I. 3. 2. Mughal production

In the 16th century Humayun brought a number of painters from Iran to India; this development greatly influenced the Mughal court style and carpets began to be made in the Persian style. With the arrival of Europeans at the Mughal court, Humayun's son Akbar (r. 1556–1605), encourage the adoption of a new naturalism in Mughal art, which merged the Indian and Iranian traditions to create a new and dynamic pictorial language.

Akbar secured the northern and central territories of India, including the prosperous Gujarat sultanate in the west, and established a strong governmental system. He was a great patron of the arts of the book, establishing a royal atelier, initially in Fathepur Sikri near Agra, then at Lahore, where he commissioned illustrated manuscripts with a mixture of Iranian and Indian elements.[65] However, as Prajnanananda clarifies, after Akbar left the city 1585, "(…) paintings continued to

64 Hallett, 2007a, p. 45.

65 "Akbar's court painters were provided with every facility for a study of the historic and contemporary examples of their art (…)" in Prajnanananda, 1985, p.75.

progress on parallel lines, the Persian and Indian styles being employed separately as two distinct methods of expression (…)" and until Akbar died in 1605.[66]

In the 17th century during the reign of his son Jahangir (r. 1605-27), Indian painters found an ardent patron of the arts. The rivalry between the Mughals and the Safavids is represented in an allegoric group portrait entitled 'Jahangir's Dream', an iconic example of how Jahangir try to uphold and legitimate his Muslim heritage through art (Figure I. 9).[67] The ruler is seen embracing Shah Abbas I on a globe, on which a lion and a lamb lie side by side.

Jahangir's patronage was predominantly focused on painting, but his support extended to other art forms, and the Persian weavers who came to the Mughal court during Akbar's reign, continued to be active.[68] As a result, the knotted-pile carpet tradition reached a peak of technical perfection with the realization of a unique Indian style, which displayed characteristic Mughal themes, such as local flora and fauna.

Like his father, Shah Jahan (r. 1628-58) commissioned many protraits of members of the Mughal dynasty.[69] His artistic patronage became more comprehensive and diffused over the whole field of fine and decorative arts. The result was the flourishing of the crafts, including

Figure I. 9: Standing on the lion, Jahangir has compassionately embraced his young and compliant brother Abbas. India, c.1618. Washington DC, Freer Gallery of Art, Smithsonian Institution, no. F1945.9a, fol. 9r (St. Petersburg album).

66 Prajnanananda, 1985, p.75

67 Levenson, 2007, p. 136; Istanbul, Isfahan, Delhi. Three Capitals of Islamic Art: Masterpieces from the Louvre collection, p.30.

68 "Akbar was apparently as impressed with Persian carpets as with Persian paintings, for his court historians noted that merchants still imported carpets from Joshaqan, Khuzistan, Kirman and Sabzewar, four cities or provinces in Iran. He noted also the appointment of experienced workmen and that carpet weavers had settled in Agra, Lahore and Fathepur. These latter references must be to Persian weavers and must refer to a period before the abandonment of Fathepur (…)" in Walker, 1892, p. 253.

69 Akbarnia et al., 2008, p. 171

textiles, that maintained the previous style by incorporating Iranian and Indian elements simultaneously.

These 'Indo-Persian' elements can be found in the 16th- and 17th-century carpets included in this study. The earliest known usage of the term 'Indo-Persian' associated with carpets can be found in Daniel Walker's 1982 publication.[70] One can speculate that some authors have used the word 'Indo-Persian' in reference to such carpets in recent years with the intention of avoiding a confused terminology, and clearly signalling that the origin of the carpets was not secure.

The adoption of the term 'Indo-Persian' by modern academics is used to describe other contexts (political or economic) that trace back to at least the 13th and 14th centuries, when texts written in Persian language began to appear in India.[71] It is believed, however, that the usage of the word 'Indo-Persian' flourished during the Mughal dynasty (1526-1858), descendent from the Timurids (1389-1508), when "the wealth of the subcontinent, and the proliferation of power centres there led to the production of a vast corpus of Indo-Persian administrative, historical, religious and poetical literature (…)".[72] This production was undertaken in the Mughal court in Agra and Delhi and at the independent courts of Persian-speaking rulers in Bengal, Gujarat, Deccan and elsewhere, including semi-autonomous Mughal provinces as far south as Madras.[73] Naturally, the close political connections between the Mughal and Safavid courts extended to the arts and carpets belonging to the 'Indo-Persian' type appear, at first glance, to reflect the courtly style of both geographical spaces. As a result, their origins are unclear, and the next chapter (Chapter II) will attempt to form a better

70 "Many Indian rugs did not remain long in India, however, Portuguese, Dutch and English trading companies all vied for Indian merchandise, including rugs, either for retrading in the East Indies of for disposition in Europe. Indian rugs became highly soughtafter status symbols in European homes, and rugs of the Indo-Persian class are frequently depicted in Western paintings" in Walker, 1982, p. 253.

71 Yarshater, 2006, p. 53: "(...) in the era of the Delhi Sultanate (q.v.) during the late 13th to 14th centuries. It was in Delhi itself, the capital of this expanding, if habitually unstable, kingdom, that most of the early Persian-language histories were written. However, it was particularly during the preceding Ghaznavid era (997-1186: q. v.) when Muslim armies penetrated deep into the Indian heartland, that poets and scholars, writing in Persian, began settling in northwestern India in significant numbers, founding the Persian-language tradition of scholarship in the subcontinent. (…) Persian-language scholarship stagnated after Timur destroyed the Delhi Sultanate in 1398, but revived and expanded exponentially during the years of the Timurid-Mughal dynasty (1526-1739). In this later period Indo-Persian historiography became a vibrant, multi-faceted tradition of scholarship, including autobiography, collections of poetry, ethical treatises (…)". p. 53. See more in: http://www.iranicaonline.org/articles/india-xvi-indo-persian-historiography.

72 Idem, p. 53.

73 Ibidem, p. 53.

understanding of their technical and aesthetic features. Certainly, they became one of the most important textile exports to Portugal as indicated by the large numbers to survive in the country.

I. 4. Portuguese interest in luxurious textiles: knotted-pile carpets

King Manuel's ambitions to secure the profitable spice trade in Malabar was a vital factor in establishing and consolidate the Portuguese plan of extending its cultural and commercial reach beyond the Iberian Peninsula. The king's sponsorship provided skilled sailors with the means to navigate successfully new routes, granting access to foreign lands, peoples and products. Via Cape of Good Hope, the newly discovered sea route revealed the existence of a dynamic maritime inter-port trade in the Indian Ocean. Other than spices, the assorted variety of products exchanged between India, Oman, Iran and, in particular, the Persian Gulf, included Arab and Persian horses, pearls, textiles and goods of the finest quality. Afonso de Albuquerque was quick to understand the economic potential of Portuguese involvement in this trading context. Albuquerque's military and strategic skills succeed in bringing King Manuel's aspiration of an overseas empire into a reality and to include important settlements in these geographical locations.

The Portuguese focused on the demands for luxury products in Europe, responding to new tastes and creating novel patterns of consumption. With the consolidation of the sea route to India the demands of wealthy European consumers for fine quality carpets could be now fulfilled. Dyeing and weaving technologies were less developed in Europe. Thus, cotton, woollen and silk products rapidly turn into highly profitable goods in this international trade.

Not surprisingly, knotted-pile carpets made of silk and precious metal threads where among the most lavish textile commodities that made their way into royal, aristocratic and palatial settings.[74] Safavid and Mughal carpet industries benefiting from these new wealthy consumers, adapted their production to create products of

[74] Spuhler, 1978. pp. 244-246; Hallett and Pereira, 2007, pp. 72-77.

more affordable quality (cotton foundation and wool knots), such as the ‘Indo-Persian’ discussed in the next chapter, to increase production and trade.

CHAPTER II

'INDO-PERSIAN' CARPETS

The great majority of Islamic carpets in Portugal can immediately be identified from their red background and symmetrically organized vine scrolls, while also sharing colors and decorative schemes. However, despite sharing similar features, they can be sorted into different types, namely: i) 'small silk Kashan' (16th century); ii) 'Tree and Animal' (16th century); iii) 'Indo-Persian' (c. 17th century), iv) 'Salting' (16th or 17th centuries)[1] (Appendix C), and v) Indian (17th to 18th centuries).

Objects belonging to the third type comprise the world's largest public collection of 'Indo-Persian' carpets. They share similar technical and aesthetic features. Understanding the group requires appreciation of how carpets are made, as well as of specific features of their design. This chapter begins by looking at the manufacturing process of knotted-pile carpets, followed by the characterization of the so-called 'Indo-Persian' type and the state of art thus far. It then presents the major questions surrounding the type and proposes an interdisciplinary methodology. Finally, it ends by describing the objects selected for this study.

II. 1. Knotted-pile carpets

The production of knotted-pile carpets requires significant organization, time, enormous resources and a high level of skills. The effective combination of all these elements will have a direct effect in the object's structural features and its pictorial appearance. Two processes, weaving and knotting, are combined on the loom[2] to

[1] Hallett, 2007a, p. 40-47; Hallett; Pereira, 2007d, pp. 72-77; Santos, 2010, pp. 4-10.

[2] "A frame used for weaving. Usually, the frame supports two beams to which warp ends are fastened. A system for raising alternate warps, a harness in effect, is termed the "heddle". A shed stick, a narrow board or lath, is used to open a passage through which the shuttle, carrying weft is passed. A reed, a form of comb the width of the loom, may be used to compress the wefts" in Stone, 1997, p. 136.

create the knotted-pile carpet structure comprised of warps, wefts and pile knots (figure II. 1).

Warps are parallel yarns running in the length of the loom where pile knots are tied, while wefts are yarns woven horizontally through warps locking knots in place.[3] Preparing the foundation is a very time consuming process but an essential step of the weaving process, during which the length and width of the carpet are established. This interwoven structure serves as the foundation of the fabric into which supplementary warps or wefts, or both, can be introduced to add patterns or textures.[4]

In the carpet literature the term 'knot' designates the interlacement around the warps of yarn, which forms the pile of the rug.[5] There are different knot types (figures II. 2 and II. 3); for some the term 'knot' is contradictory as the ends are not twisted about each other and drawn tight as in a true knot.[6] This is the case of the asymmetrical knot open to left (also known as the Persian knot) frequently found in Iranian and Indian carpets from the Classical period. The knots are applied one after the other, each corresponding to a point in the carpet knot-plan (figure II. 4).[7] This procedure is followed by one or more weft yarns placed between each row of knots, which prevent any adjustment or amendments in the carpet structure and design afterwards.[8]

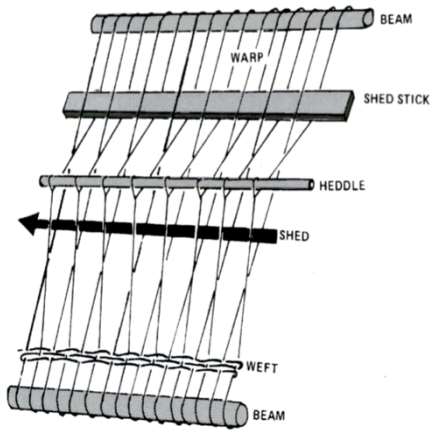

Figure II. 1: Loom scheme with its different components. Published by Stone, 1997.

[3] Stone, 1997, p. 136.
[4] Bier, 1987, p. 325.
[5] 'The pile is mostly of wool of some kind, and is, of course, diversely coloured as the design requires (…) sometimes so short as almost to show the knots, and sometimes quite long (…) the surface is bound to be more or less irregular, so that the final operation is to clip the ends of the pile with shears and bring it to a uniform level' in Tattersall, 1983, pp. 14-15.
[6] Beattie, 1976, p. 29.
[7] 'A "blue print", so to speak, for a carpet design. Arranged as colored squares on graph paper, a knot plan can serve as a reference for many individuals weavers, allowing the replications of a single design' in Denny, 2014, p.142.
[8] "(...) once the weft is passed after a row of knots, the weavers's decisions are locked into the carpet for its lifetime. Compromises, mistakes, abandoned ideas, changes in the width of borders or the colors of

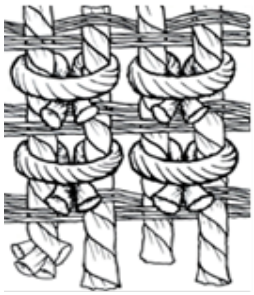

Figure II. 2: Symmetrical knot scheme. Published by Beattie, 1976.

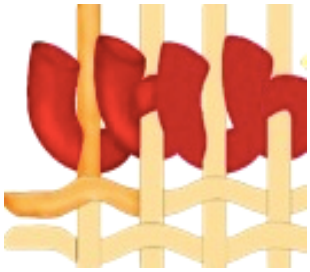

Figure II. 3: Asymmetrical knot open to left scheme. Published by Frade et al., 2010.

Figure II. 4: Example of a graph-knot plan. Published by Denny, 2014.

The excellence of a design is dependent on the choice of materials used to produce a carpet: fibers (pile and foundation) and dyes (colored fibers). Through the study of classical carpets it is acknowledged today that both vegetable and animal fibers were used. These can be found in the foundation and pile in different combinations, for example: 1. Silk and cotton (foundation) and wool (pile) (see Appendix C, figure 2), 2. Cotton (foundation) and wool (pile) (see Appendix C, figure 3), and 3. Silk (foundation and pile) (see Appendix C, figure 1); the latter predominantly associated with high quality carpet production due to the inherent cost and high knot density created.

The choice of carpet knots and types of fibers can produce significant variances in the pile density, which in turn affects the execution of more sophisticated designs. Certainly, one would expect symmetrical knots to be safer as their ends are pulled together between two warp threads (figure II. 2). However, asymmetrical knots have considerably less volume as only one side of the knot is wrapped around the warp thread (figure II. 3), particularly when using a thinner fiber such as silk rather than wool. This allows not only to increase the knot density when packing them, but also to accomplish superior results when performing the curvilinear elements of their designs (figure II. 4).

The best wool is used in the carpet pile, often from the first clip or from the neck and shoulders. From washing to plying wool preparation is subjected to several stages that entail special knowledge, namely, washing, grading, combing, coiling, spinning and

motifs, and improvisations to avoid knotting one's self into a corner – they are all there for us to see" in Denny, 2014, p. 31.

plying. The single yarns[9] (figure II. 5) are then constructed with the principle of arranging the fibers evenly and in parallel to each other during the spinning process, which can be executed using a hand-held spindle (figure II. 6) or mechanical spinning wheel. The process of plying entails combining single threads – twisting them together in the opposite direction in which they were spun following the direction indicated by the central bar of the letter Z and S (figure II. 5 and II. 7).

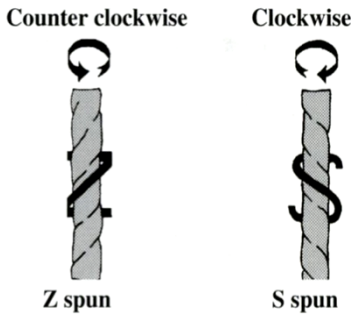

Figure II. 5: Schemes of plying of several cables. Published by Thompson, 1993.

Figure II. 6: Spinning wool with a spindle in Turkey. Published by Stone, 1997.

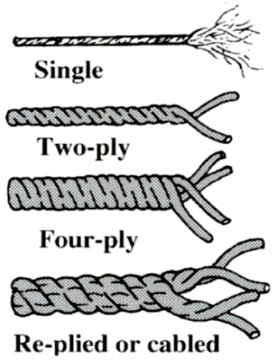

Figure II. 7: Scheme of Z and S spun. Published by Stone, 1997.

The number of strands (i.e. Z2S or Z9S) and their tension are therefore two major conditions to be considered when looking at yarn variation, as both have a direct effect on its thickness.[10] Thus, the knot density is also influenced by the yarn structure.

Figure II. 8: Pots used to obtain the different colored skeins in a workshop.
(Web: http://dexterapparels.com/about.html, 2015).

[9] "(...) yarns are continuous strands made up of textile fibres, and the fibre is the basic physical structure or element, which makes up textile products. Each individual fibre is made up of millions of individual long molecular chains of discrete chemical structure. The arrangement and orientation of these molecules within the individual fibre, as well as the gross cross section and shaped of the fibre (morphology), will affect fibre properties, but by far the chemical structure of the long molecular chains which make up the fibre will determine the basic physical and chemical nature of that fibre." in *Fibre classification"* in Needles, 1981, p. 1-2.

[10] For further information about preparation of fibers for carpet production see Thomspon, 1993. This is still an indispensable reference to the understanding of carpet making.

Likewise, the high cost of labor and materials were significant in the final step in the chain of fiber preparation: dyeing. This craft involved high-skilled individuals capable of using the natural dyestuff available to produce a beautiful palette of fast colors (figure II. 8). From different plants or insects a skilled dyer has the knowledge to extract and produce a palette ranging yellows, oranges, reds, pinks, blues, greens and browns. Additionally, attaching their bright colors to various fibers by means of different mordents (alum, iron, etc.) is not a process that is easy to master. Thus, dyeing fibers was often an inherited skill, passed only between members of a family or workshop. Further details on the use and preparation of fibers and dyes will be presented and discussed in later chapters of this work (see Chapter III. Fibers and Techniques and Chapter V. Colors and Dyes).

As discussed by several authors craft habits rarely change, differences in the interlacing structure of the knot, warp and weft, together with dyeing are likely to determine different places of production.[11] Each step of carpet manufacture has a significant impact on the final result. Moreover, the design and the high-skills of a weaver required to read and execute it are two additional key elements to assure carpet quality during the manufacture process. Carpet production can be grouped into four categories proposed by Jon Thompson: tribal and domestic weavings, cottage carpets (figure II. 9), workshop or town carpets[12] (figures II. 10 and II. 11), and court carpets.[13]

Considering the characteristics of the carpets in this study, namely their designs, materials and techniques, particular attention is given to the urban carpet industry in the 17th century and its relationship with court production. As demonstrated above, carpets require an enormous pyramid of trades and skills for a fine object to be produced. The production cost is influenced by several factors: sourcing and preparation of fibers, yarns, dyes, the provisions and skills related to foundation and weaving manufacturing, as well as the means to access markets. Understandably, these elements were reflected

[11] Cohen, 2007a; Thompson, 1993 and Walker, 1998.

[12] "The workshop themselves were sometimes staffed by craftsmen in the direct employment of the court, but more often they acted as suppliers of goods of standard and design specified by the royal atelier" in Thompson, 1993, p. 147.

[13] See Thompson, 1993 for further information on carpet production.

in the selling price of different carpet types found in markets in various regions of Iran and India in the 16th and 17th centuries.[14]

Figure II. 9: Example of production from a cottage workshop in Bijar (Persia). Published by Thompson, 1993.

Figure II. 10: Example of workshop or town carpet production in turkey, in which the weavers are replicating the design using a knot-plan. Published by Thompson, 1993.

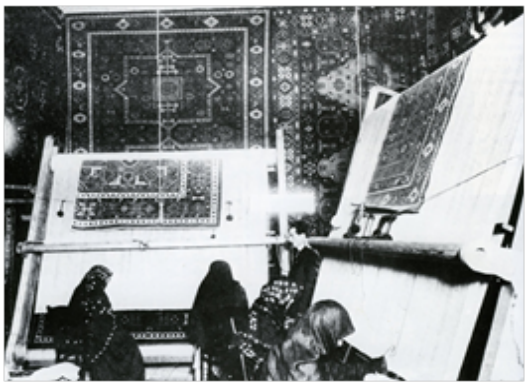

Figure II. 11: Example of workshop or town carpet production from Caucasus, using a quarter plan of a carpet sample to replicate the designs. Published by Thompson, 1993.

II. 2. Defining 'Indo-Persian' carpets

Carpets belonging to the 'Indo-Persian' group share similar technical and aesthetic features, displayed in objects with various dimensions, ranging from approximately two to thirteen meters in length (see carpet 26.277, appendix D). The designs are achieved using asymmetrical knots open to left, also known as the Persian knot.[15] As discussed

[14] A more detailed discussion on the commercial aspects of carpet production and distribution will be provided in later chapters.
[15] Hallett, 2007c, p. 90.

previously the knot density can vary according with the materials used and size of the carpet but generally ranges between 1500 and 3000 per square decimeters for the 'Indo-Persians'.

The artistic vocabulary comprises motifs such as palmettes, chenar leaves[16], lotus flowers, horseshoe-shaped and undulating S-shaped cloud bands (*Tchi* clouds) deriving from Chinese art (table I. 1). These are displayed intertwined within layers of delicate vine-scrolls commonly exhibited on red fields in numerous variations. In addition, palmettes, chenar leaves or lotus flowers facing inwards and outwards are displayed in an undulating rhythm in blue or green borders. The replication and level of complexity of their field and border designs will be discussed in detail in further stages of this study (see Chapter IV).

Table I. 1: Motifs most commonly found in the field of carpets belonging to 'Indo-Persian' group

Lotus Palmettes		Lotus flower		
Chenar leaf		Horseshoe-shaped and *Tchi* Cloud bands		

Another significant distinguishing feature of the 'Indo-Persian' carpet type is their design composition. The vast majority display field designs based on a symmetrical quarter plan developed in book illumination and seen also in court carpet production (figure II. 12 and II. 13).[17]

The relatively high quality of the weaving is noticeable from the well-resolved corners where a motif is neatly placed on the diagonal, together with the successful achievement of curved and diagonal lines which represent a considerable challenge in weaving (figure II. 12). This is further visible in the richness of the color palette, ranging

[16] Shaped as a Plane tree leaf (Pers. *Chenar*). For further information on this matter please see: http://www.iranicaonline.org/articles/cenar-the-oriental-plane-tree-platanus-orientalis-I.
[17] Thompson, 1993, p. 147.

from eight to twelve different colors (hues). These features suggest they were likely produced in a workshop, which was reasonably well organized and well equipped, probably in an urban environment, such as a town or city.[18]

Figure II. 12: Image of single quarter plan belonging to object 10Tp from MNAA, Lisbon

Figure II. 13: Carpet design quarter scheme .

However, understanding their precise circumstance of production (origin) – whether they were made in Iran or in India, or how the transformation in design occurred for the 'Indo-Persian' type, and when, remains to be solved. Moreover, the large numbers that survive until today in western collections, place more questions regarding the context of consumption. The next section looks at the challenges around the study of the 'Indo-Persian' carpets.

II. 3. State of the Art

Often carpet studies face major obstacles, such as the near absence of facts that can allow us to reconstruct their history, the rarity of sufficient surviving examples, and the lack of information about authorship or production dates. The notable exception is the Ardabil carpet in the Victoria and Albert Museum (London) (Appendix C), which displays a date (1539-40), although no consensus concerning its origin has been attained. The lack of precise data for developing a secure system of classification for Iranian carpets has led to the development of groups, such as the 'Indo-Persian' type, whereas there is no evidence as to where this particular carpet type could have been produced. Some authors point to cities such Yazd and Isfahan as possible centers of its production in Iran.[19]

[18] Thompson, 1993, p. 135-36.
[19] Hallett, 2007a, p. 46; Cohen, 2004, p. 92.

Conversely, few European written sources are known for providing reliable information on Iranian or Indian carpet production, as Friedrich Sphuler has pointed out, there is only one European 17th-century reference that confirms the precise location of manufacture of a particular carpet type in Iran – the so-called "Polish" carpets – and that is the order of carpets from the King of Poland to weavers in Isfahan.[20] Other references to carpets merely indicate production in a particular place, without mention to what kinds of carpets were made there (apart from the occasional reference to their quality or materials).[21] Moreover, carpets were major commercial products that circulated widely through the Islamic world. Thus, no assumption can ever be made regarding their origin based on the places where they were being sold. One must remember that while their use was strongly dependent on the context of their original production, they could still be sold elsewhere and resold again in different places and at different times. Therefore, the study of the historical and art historical contexts surrounding the production and consumption of 'Indo-Persian' carpets is required.

The studies from Charles Grand Ellis[22] or Friedrich Spuhler[23] around carpet classification in the 20th century brought to light a more systematic pursuit for questions of origin and date. Attempts to associate carpets with productions centers, while recognizing their design chronological evolutions have been made using historical carpets. May Beattie's and Steven Cohen's works offer important evidence for how technical differences can contribute to distinguish Iranian and Indian production, and hence assist with determining the origin of 'Indo-Persian' carpets.[24]

[20] "Their dates are supported by documents: in 1601, the Polish King Sigismund Wasa III ordered such a carpet from Kashan" in Spuhler, 1987, p. 69.
[21] See Hallett, 2007a, p. 46: "In three parts of Persia are manufactured carpets, which the Portuguese call *alcatifas* and the Persian call *kalícha*, the richest and finest and most esteemed come from Yazd. The second best are those from the kingdom of Kirman, the third from Khurasan; They are also made in Agra, Bengal and Cambay, but not the fine ones." in the *The Travels of Pedro Teixeira*, 1902, p. 243.
[22] Ellis, 1988.
[23] Spuhler, 1987.
[24] Beattie, 1972; Cohen, 2001, pp. 74-85; 2006, pp. 26-43; 2007a, pp.115-121; 2007b, pp. 123-130.

In recent years carpet studies have revealed the potential of materials analysis, particularly for questions of origin and date.[25] It is known that fibers and dyes were sourced from geographic regions near production centers. Hence, understanding the type of materials used to produce a carpet or how they are prepared can reveal groups of carpets and their general or specific location of production[26]. However, the lack of published results for material analysis performed on related examples belonging to this type increases the importance of further studies. With the exception for the work of Hallett, Cohen, Heitor and Armindo[27] around the 'Indo-Persian' group, no systematic study has yet attempted to relate information from 16th- and 17th- century pictorial sources with knowledge of the technique, materials and styles of the carpets themselves, to look at how, when, where and why these carpets were made, or to explain the presence of such high number of extant examples in Portugal.

For questions of dating, the situation is hindered by the absence of any inscription or related information that could be used to confirm their production date. The work developed by Jessica Hallett on Islamic carpets in Portugal based on Portuguese written and pictorial sources, however, has revealed some important information for beginning to tackle questions regarding the production of 'Indo-Persian' carpets.[28] Written sources offer important historical evidence that attests the arrival, high cost and appreciation for these objects.[29] Some inventories even provide physical descriptions, while accounts of the Asian products that berth in Lisbon 16th and 17th centuries provide the prices of Islamic carpets.[30]

Pictorial sources, on the other hand, provide an excellent means for tracing the chronological evolution of carpet designs.[31] In Portugal the presence and value of

[25] Armindo, et al., 2008, pp. 960-966; Heitor, et al., 2008, pp. 161-168; Santos, 2010.
[26] Walker, 1997.
[27] Heitor, et al., 2008, pp. 161-168; Cohen, 2007a, pp. 115-121; Cohen, 2007b, pp. 123-130; Armindo, et al., 2008, pp. 960-966.
[28] Hallett, 2007a, 2007c.
[29] Information concerning the quantity of purchased carpets or their physical descriptions can be found in the inventories of Queen Catarina of Austria (1507-1578) and Duke Teodósio I (1510-1563), both consumers with great appreciation for these objects. For further information please see: Hallett, 2007a, p. 41.
[30] Idem, p. 40.
[31] Mills, 1975; Mills, 1978, pp. 234-243; Mills, 1983; Mills, 1988, pp. 42-44; Ydema, 1991; Hallett, 2007d.

Iranian carpets can be verified since the 16th century[32] by the portraits of King João III (r. 1521-1557) and Queen Catarina of Austria that include the first depictions of these objects in European paintings.[33] Moreover, painted depictions of a new border type comprising a continuous vine meander, supporting large inward-facing and outward-facing plane tree leaves and outward-facing palmettes appear by the end of the 16th century. On the basis of pictorial sources, Hallett was able to confirm that Islamic carpets were fashionable in Portugal, and that they were mostly represented in religious contexts or in portraits of royalty.[34] Besides confirming the high social status of their consumers and which types of carpets were being brought to Europe and sold in the Portuguese market, paintings provide a *termini ante quem* date for the depicted carpet types.

Despite offering significant information for understanding the chronological evolution of the 16th-century carpet industry and the acceptance of carpets in the Portuguese market as luxury products, both written and pictorial sources present limits in regard to providing answers concerning the origin and date of carpets and particularly of the 'Indo-Persian' type. It is known that in general these carpets followed the fashion of court workshops, but cheaper materials and swifter production methods.[35] One of the features worth examine is whether the borders were customized, and therefore functioned as workshop signatures that could identify specific manufacturers. If this were indeed the case, then borders could be used as a potential tool for determining the origins of these carpets.

As explained above, the distinction between carpet groups has been greatly improved by new methodologies that combine technical and material analysis. The work developed by Jessica Hallett and Steven Cohen, since 1999, based on analysis of structure, materials, colors and decorative patterns attributes the 'Indo-Persian' type to Iran. Moreover, due to "(…) surprisingly homogeneous in their technical aspects,

[32] Hallett, 2007b, p. 79:"Persian carpets were worth three times the cost of Turkish wool carpets with equivalente dimentions and at least three and even fifty times the price of a painting by Francisco de Campos".
[33] Idem, p. 79.
[34] Hallett, 2007a, p. 45; Hallett, 2007d, pp. 181-198.
[35] Walter, 1997b, p. 24; Hallett, 2007a, pp. 45-47.

suggesting a single, coherent weaving tradition"[36]. Weaving structure which is typical of Persian construction[37] was found in vast majority of the objects, while other type of carpets displayed – Z5S, Z6S, Z7S or Z8S white cotton warps, 2Z beige cotton wefts, 2Z wool pile - typical of North Indian construction. According to Cohen these distinguishing features allowed the exclusion of carpets from the 'Indo-Persian' type as possible products of Mughal manufacture and therefore to be attributed to Iran instead of India.[38] This information is recognized and reinforced by Thompson: "(…) there is no longer any need for confusion because those produced in Iran can be distinguished from the Indian pieces on technical grounds. As for where in Iran they were produced, this problem is still unsolved".[39] This notion, however, continued to be question and John Mills, in his review of Hallett's work, suggested that one of the 'Indo-Persians' was possibly Indian even though it shared the same technical features.[40]

In addition to a coherent technique, the range of colors in the 'Indo-Persians' studied confirmed by dye analysis performed using High Performance Liquid Chromatography (HPLC), exposed the use of *Kerria* sp. an expensive red insect dye (as opposed to cochineal found in only reds from 'small silk Kashan'), madder together with a yellow dye source for the oranges, which is also found in yellows and identified as probably weld[41]. However, less than 10% of the Portuguese collection was submitted to dye analysis not being sufficient to establish a firm conclusion.[42]

This work takes an interdisciplinary approach –Art History, History and Conservation Science (figure II. 14), towards the questions surrounding the so-called 'Indo-Persian' carpet type: where were the 'Indo-Persian' carpets being produced? Iran and/or India? Was it localized production or widespread? When were they produced? How did the type developed and why?

[36] Heitor, et al. 2007, p. 167.
[37] Z4S white cotton warps, 2Z beige cotton wefts, 2Z wool pile with asymmetric knots open to left.
[38] Cohen, 2007b, p. 128.
[39] Canby, 2009, p. 210.
[40] Mills, 2008, pp. 133-4.
[41] Heitor, et al., 2007, p. 165.
[42] Heitor, et al., 2007, pp. 161-168; Arminho, et al., 2008, pp. 960-966; Santos, 2010, pp. 10-22.

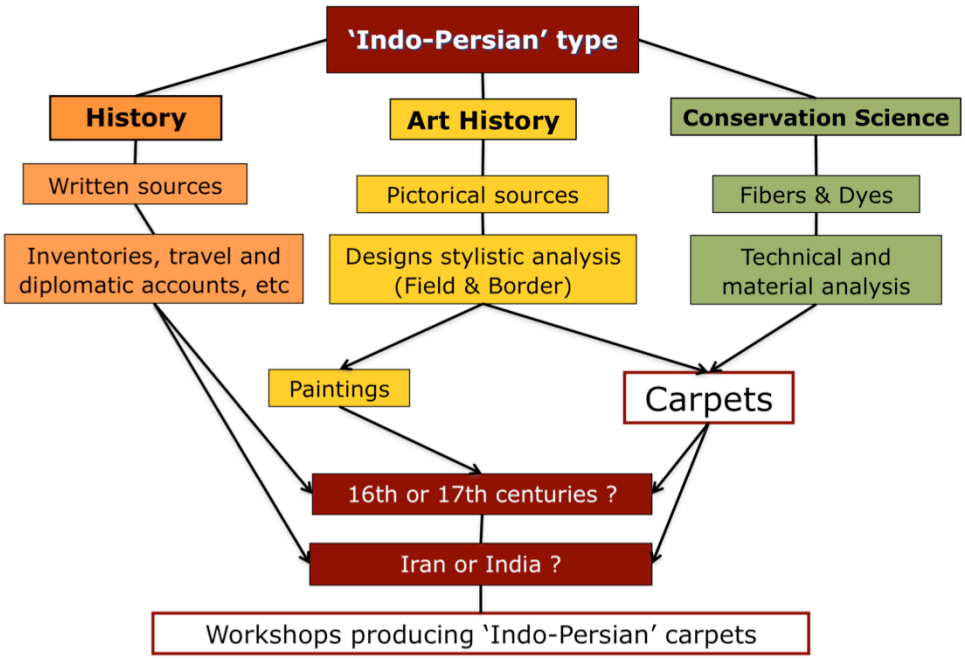

Figure II. 14: Diagram of the project methodology.

Moreover, this study aims to explore production and consumption by conducting a close examination of materials, techniques and design, supported by science, as a complementary tool for assessing the spatial and temporal dimensions surrounding the 'Indo-Persian' type.[43]

II. 4. Questions and Methodology

As demonstrated above the work of Mills, Ydema or Hallett attempting to either associate carpets with production centers or with a relative date, have produced positive outcomes using historical carpets. Therefore, in this study 59 carpets – including eleven fragments – from the 16th and 17th centuries were selected to serve as historical evidence to assess these questions. Comprised in this selection are seven carpets recognized as 'Indian', two as 'Early Safavid' objects, and the remaining fifty carpets are labeled as 'Indo-Persian' by their holdings institutions, thus their origin is described in this study as 'Iran?' (figure II. 15) and refined through the analyses undertaken here. Additionally, in an effort to establish potential relationships between

[43] Walter, 1997b, p. 24; Santos, 2010, pp. 10-22; Hallett and Santos, 2014, pp. 257-264.

the selected examples in Portugal – 49 carpets from Museu Nacional de Arte Antiga (MNAA) in Lisbon and Museu Nacional Machado de Castro (MNMC) in Coimbra – ten objects were selected from collections in the United States of America – The Textile Museum (TM), the Corcoran Gallery of Art (CGA) and National Gallery of Art (NGA) in Washington, DC. Detailed information on each object can be found in Appendix D.

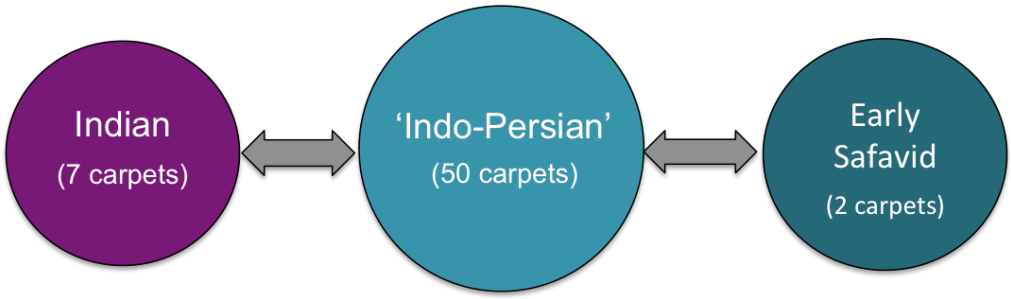

Figure II. 15: Distribution of objects included in this study: their Institutional classification and correspondant quantity.

Data from stylistic, technical and material analysis (fibers and dyes), together with collected art historical information is used to establish different groups of carpets. The results are used to relate the various groups with a geographical origin. Likewise, on the basis of their field and border stylistic features, the results allow to trace the chronological transformations of their design, offering a date for production of different objects under the 'Early Safavid' and 'Indo-Persian' types. [44]

Stylistic - Design Analysis

Several field and border designs were recognized on the basis of extensive stylistic analysis from extant carpets. This analyze is followed by combining field and major border design types together to sort different stylistic groups of carpets, with the aim of improving the understanding of a chronological evolution and context of production (court, city, etc.), and tackling questions regarding the geographic location for their production. However, determining the origin of the resulting stylistic groups requires the use of technical and material analysis. For establishing dates historical carpets are

[44] With the exception of Indian carpets.

compared with their depictions in Portuguese and Dutch paintings from 16th and 17th centuries as discussed below.

Technical Analysis

The weave structure is very important and has been used to associate objects with more specific origin, particularly allowing the support of Iranian or Indian attribution.[45] With the aim to better understand and systematize the results of technical data obtained from past collection surveys, a carpet analysis datasheet was created (Appendix E).[46] This datasheet comprises four main sections namely, *object identification, formal description, material and technical characterization and analytical exams.* This document was design to include and compile information from the most relevant aspects of carpets analysis, serving as a tool for this project and for museums and institutions housing these objects.

Material Analysis

In the last decade dye analysis has significantly improved our understanding of these carpet industries, by discerning different traditions in carpet production and their possible origins, as well as conservation challenges presented by the objects themselves. This project focuses on red, pink and yellow colors found in 16th- and 17th-century carpets attributed to Iran and India (Mughal and Deccan), together with orange colors from carpets attributed to Iran. These colors have proven to be extremely useful for determining regional use of dyes and the possible area of production of these objects. Additionally, browns were also included in this study as the number of published dye results for carpets are even smaller and the few samples analyzed until now belong to the most recent study of three 'Salting' carpets. The analysis of the brown color presents new possibilities for gaining a better understanding of different centers of production and distinguishing them, especially as some browns may have been achieved by using natural brown wool rather than by submitting the fibers to a dyeing process, making it another possible feature for

[45] Steven, 2007b.
[46] The development of this datasheet was possible thanks to Dr. Jon Thompson's (Islamic carpet expert) teachings.

distinguishing origin. A total of 762 historical wool textile samples were collected from 59 objects and over 800 dye-analyses were conducted using High Performance Liquid Chromatography coupled with Mass Spectrometry (HPLC-MS) and interpreted on the basis of statistical methods. HPLC-MS is a high sensitivity analytical chemistry technique that combines the separation capabilities of liquid chromatography with the molecular identification of mass spectrometry. Moreover, 16 historical samples from the pile - red, yellow, pink, orange, red and brown colors - were analyzed with optical microscopy to understand if one or more types of fiber were being used in different color batches.

For question of origin several chemical standards, insect species, and sixteen wool samples dyed using plants collected in Iran were used to build a reference database to further improve the identification of dye compounds present in the historical wool samples. Furthermore, the resulting data is interpreted by statistical methods: 1) by looking into results from individual colors, 2) by combining results from red and yellow colors present in the majority of the objects and 3) subsequent groups of objects are interpreted.

As for dating Portuguese documents offer an initial date for the arrival of Islamic carpets, which was not before the 16th century.[47] Travel accounts testify the political and socio-economic relationships between Portugal, Iran and India and provide evidence of production of luxurious textiles, including carpets, in Iran.[48] Moreover, inventories serve as evidence to Portuguese consumption of luxurious carpets in the late 16th- and early 17th-centuries, where carpet descriptions indicate patterns of taste.[49] This information however is fairly limited and as result designs from historical carpets are analyzed along with paintings to recognize their chronological evolutions. This methodology starts with the work developed by Onno Ydema on border designs and Jessica Hallett on fields based on extant objects in Portuguese collections and develops a new approach, which includes additional

[47] Hallett, 2007a, pp. 39-40.
[48] Albuquerque, 1884; Calouste Gulbenkian Foundation, 1972; Piacentini, 2008, p. 12; Ferreira, 2011; Gil, 2012;
[49] Hallett, 2007a, p. 40; Hallett, 2007b, p. 84.

paintings. It attempts to establish absolute dates for each border type using not only depicted carpets but also existent carpets and then recognizes groups and establishes a chronology for production and consumption. Very rarely paintings offer information about the precise location of production of the carpets represented. Portuguese pictorial sources verify the presence and use of knotted carpets in palaces and churches.[50] Their high value and appreciation, however, cannot be disputed, as their depictions prove their use as symbols of luxury and power.

To summarize, the identification and characterization the materials – fibers and dyes – along with the color palette and woven technique are features that not only define the type but are also of extreme importance for reconstructing workshop traditions and the place and date of manufacture. The following chapter – *Chapter III Fibers and Technique* offers a comprehensive analysis of fibers and techniques used in the carpets included in this project to begin to understand the specificity of their manufacture. The subsequent chapters will focus on their design analysis (Chapter IV) and colors and dyes (Chapter V).

CHAPTER III

FIBERS AND TECHNIQUE

Characterizing a manufacturing tradition, such as how the 'Indo-Persian' carpets in this study were produced, requires the identification and systematic description of material properties and technique. A comprehensive carpet analysis should always include a description of the object's function, dimensions, the type of fibers used in the woven structure (warp, weft and pile), the type of structure in the edge and end, together with other unusual features, as well as the range of colors and dyes, and state of condition.

Accordingly, the analysis and characterization of fibers and weave of the 59 carpets included in this study was performed. Different analytical methods were applied according to the nature of each material and the results provide information on material preparation and manufacturing traditions of the 'Indo-Persian' carpet workshops. This chapter looks into the fibers and weaving structures, followed by the corresponding sampling procedures and analytical methods used for their study before addressing their results.

III. 1. Fibers

Fiber identification has always been fundamental for those involved with textiles. In the past few decades, considerable research has been carried out worldwide to understand and quantify the effects of fiber types and processing parameters on the behavior, performance and properties of yarns and even the resulting fabric.[1] There is a wide range of techniques used to identify fibers and there is no 'standard' method, but in general, light microscopy is the simplest and most often applied.

The textile industry has used many different kinds of fibers as raw materials for manufacturing different goods. Earlier industries used fibers that occur in nature, and

[1] Botha and Hunter, p. 235.

can be classified as vegetable, animal and mineral.[2] Though vegetable fibers were likely the first to be used for spinning and weaving, animal fibers such as skins and furs were undoubtedly the earliest used for clothing by early human.[3] Radiocarbon dating can use fibers to establish a period(s) for possible production. Yet, the results are presented based on statistical calculations, one still needs to consider factors such as the nature of the sample, which tends to shred into fragments when working with micro-samples, and the presence of other organic contaminants. Precisely when animal hair started to be cut, twisted into yarn and then later woven to produce a textile commodity remains unclear. However, according to the literature, by the seventh century BCE the Phoenicians were buying homespun woolens from the Israelites and shipping them to England to barter for tin and raw wool.[4]

Factors influencing fiber choice and use include their capacity to be spun, their availability in sufficient quantity, the cost or economy of production, and the appeal of their properties to consumers. [5] Organic fibers are comprised of polymers, long molecules formed by small units (monomers) joined together in long polymeric chains. These polymeric chains are quite well organized in textile fibers and each fiber type embodies a specific structural arrangement.

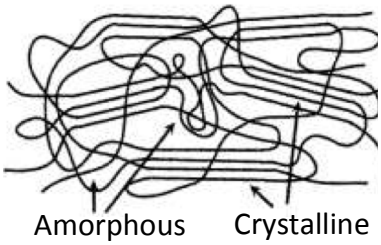

Figure III. 1: Crystalline and amorphous areas in a polymer

Often, a polymer contains a mixture of chains which are either aligned (crystalline areas) or unaligned (amorphous areas) (figure III. 1). Strong and fairly tenacious fibers such as linen have higher quantities of crystalline areas, while amorphous fibers are usually more fragile but have very high elasticity levels, such as wool. Cohen explains that Iranian carpet weavers abandoned the practice of knotting with fine goat hair after the 16th century for reasons that remain unknown.[6] In addition, the most luxurious Iranian carpets continued to be knotted with silk, or silk

[2] Corbman, 1975, pg. 3: "Vegetable fibers, found in the cells walls of plants, are cellulosic in composition. Animal fibers, produced by animals or insects, are protein in composition. The mineral fiber, arbestos, in mined from certain types of rock".
[3] Cook, 1993, p. 80.
[4] Idem, p. 80.
[5] Corbman, 1975, pg. 3.
[6] Cohen, 2003, p. 129.

supplemented with metal-wrapped thread.

The constant presence of cotton warps and wefts and wool knots are a recognized diagnostic technical feature of carpets belonging to the 'Indo-Persian' type. To accomplish the aims of determining the origin and date of 'Indo-Persian' carpets, this project includes carpets belonging to earlier production types or associated with specific workshop production (see carpets 1942.9.477 and 12Tp in Appendix D).

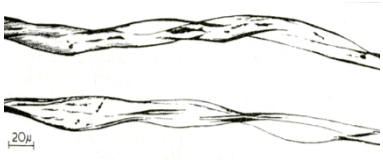

Figure III. 2: Longitudinal view of mature (above) and immature (below) cotton fibers, displaying typical convulsions.

Figure III. 3: Longitudinal view of a wool fiber.

The selection of objects for this study is based on their attribution to Iran or India, in order to recognize differences in fiber types, namely cotton and wool. Due to the intrinsic variability of most textile materials, it is fundamental that a representative sample of fiber is obtained for testing. In fact, as stated in the literature the first step for accurate fiber identification is to obtain a reasonably representative sample for examination.[7] Cotton fibers can be found in a great variety of shapes and forms but their distinctive feature is the convolutions – twists in the fiber (figure III. 2). On the other hand, a typical characteristic for wool fiber identification is the scaly outer cuticle layer (figure III. 3).

As Greaves states, "the nature of this scale pattern allows the specific type of animal fiber to be identified and enables a distinction to be made between wool, cashmere, camel hair, yak and mohair, for example".[8] When the fibers are undyed and non-pigmented, a straightforward examination of the cuticle and comparison with reference samples is possible. As a result, general microscopic techniques will permit positive identification, while scanning electron microscopy (SEM) will display the fiber surface with even greater clarity than by using a light microscope.[9] Examination of longitudinal and cross-sectional views of natural fibers from x100 to x500 magnification

[7] Greaves, P. H.; Saville, B. P., 1995, p. 5.
[8] Idem, p. 5.
[9] Ibidem, p. 39.

gives detailed information with regard to the surface morphology of the fiber.[10] However, most finished textile goods have heavily dyed or pigmented fibers preventing the scale pattern to be visible with transmitted light. In addition, when looking at works of art, and in particular historic textiles, the number and small size of samples creates a significant challenge.

III. 1. 1. Fiber analysis

Fiber analysis was performed on nine carpets belonging to Museu Nacional de Arte Antiga; namely, two attributed to India and seven to Iran. A total of 16 historical samples from the pile - red, yellow, pink, orange, red and brown colors were collected with the aim of understanding if one or more types of fiber were being used in different color batches.

Fiber identification was performed at José de Figueiredo Laboratory, from Direcção Geral do Património Cultural (LJF-DGPC) in Lisbon, using a Leitz optical microscope with IM1000 V1.20 software. Longitudinal sections of the historic sample fibers can provide evidence for the nature or type of fiber, but not for the species. As a result, cross-sections were necessary, and due to the small size of the historical samples, a resin cross-section methodology was used (Appendix F). Transverse cuts 20 μm thick, were made using a microtome (Leica RM2155) and the cross-section was analyzed under the optical microscope using x100 or x200 magnification.

Results from both longitudinal- and cross-sections of historical samples were able to confirm the type of fiber. For all the examined samples wool was used for the carpet knots (figure III. 4) and cotton for the foundation (figure III. 5). Unfortunately, the lack of reference material, and small sample amount made it impossible to differentiate the precise animal species. In addition, the examination of the physical properties of the fibers using optical microscopy did not enable further refinement beyond identifying wool and cotton. Thus, additional methods for fiber analysis are required

[10] Needles, 1981, p. 17.

Given the limitations imposed by historical textile samples, it seems that fiber DNA sequencing may be a promising next step in fiber studies to resolve questions concerning the origin of historic textiles.[11] It is hoped that future financing will allow for these specialized analyses to be undertaken. This project focused instead on dyes for the purpose of associating these objects with specific workshop locations (Chapter V).

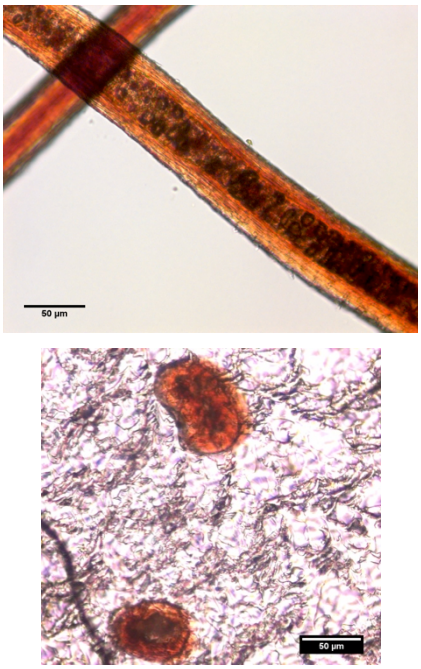

Figure III. 4: Wool brown fiber taken from knot pile belonging to carpet 1Tp. Longitudinal (above) and transversal (below) views from optical microscopy (x50 µm).

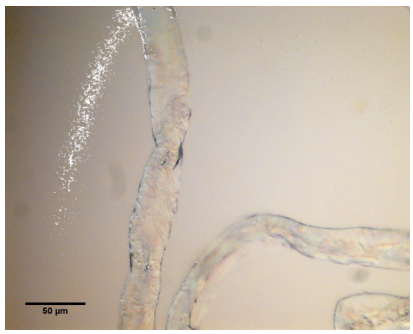

Figure III. 5: Optical microscopy of cotton warp thread belonging to carpet 18Tp (x50 µm).

III. 2. Weaving structure

The woven structure of all the objects selected for this study was examined by previous researchers.[12] However, as Stone states, "the process through which a fabric structure is created is distinct from the structure itself" and different techniques can produce equivalent structures. [13] Thus, in addition to offering a description of all the technical aspects of each carpet and clarifying the importance of the weaver's skill, tools and looms, this study provides a new reassessment of earlier examinations. As

[11] Schmidt, et al. 2014.
[12] Hallett et al., 2007; Denny, 2006; Sumro, Krody. *Unpublished report on technical analysis of five carpets to Corcoran Galleries of Art* (Washington, DC), 2013, pp 1-7.; Denny, W. B. *Unpublished survey of carpets undertaken to Corcoran Galleries of Art* (Washington, DC), 2006; Torchia, 1997.
[13] Stone, 1997, p. 222.

affirmed by Edwards, “Such fabric must consist of two main elements: a woolen pile – to give thickness and warmth, and to embody the color and the pattern; and a solid back or foundation to which the tufts of wool could be attached”.[14]

Preferably, an analysis focused on weaving structures should describe the following structural properties: warps, wefts, knots, edges, ends and some other unusual features. The *Carpet Analysis Datasheet* developed for this project includes detailed information on such structural properties, together with other relevant information about the object, such as identification, formal description, material characterization and analysis (see Appendix E).

The general condition of the majority of the objects included in this study is good or very good. Unfortunately, some structural properties mentioned can no longer be seen in some of them, simply because they are fragments or display areas of damage or restoration (patches and other reinforcements). These limitations can have a direct impact on defining other carpet features, such as edges, sides or ends, thus limiting the completeness of the information provided. Therefore, to ensure a high level of consistency in the weaving analysis, the best method for comparing different woven structures is to rely on the observation of three main features: pile, warps and wefts. Nevertheless, whenever possible the edges, ends and other particular features should also be analyzed and any observations included in the correspondent datasheet (see Appendix D).

III. 2. 1. Weaving analysis

This study focuses on pile (knots), warps and wefts. A thread count was used to examine various features: fiber type, direction of spin, ply of the yarns used for the warps, wefts and pile. The first step is look at the pile to determine the length, knot type and density (figure III. 6).

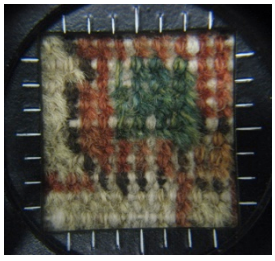

Figure III. 6: Detailed image from the back of carpet T749 using thread count.

This is followed by analysis of the warps, the type of fiber, the spin and ply of the threads, and the degree the

[14] Edwards, 1975, p.22.

warp is depressed. Finally, the weft threads are examined to determine the fiber type, the configuration (spin and ply) of the yarn, and the number of wefts between rows of knots.

The results of the analysis of the weaving structure are presented in table III. 1. With some exceptions the majority of this data is consistent with the results presented by previous technical analyses. However, examination of carpets based on their warps, wefts and pile allowed for the establishment of seven groups. The largest group comprises 46 of the 59 objects in this study and is designated Group I.

Table III. 1: Distribution of objects according to the results of weaving analysis.

Group	Knots	Warps	Wefts	Object (Inv. Number)
I	Wool (2Z, 3Z)	Cotton (Z4S)	Cotton (2Z) (White or Beige)	26.277; 26.300; 26.285 T748; T749; T750; T751; T753; T754; T756; T757; T758; T759; T760; T761 1Tp; 2Tp; 10Tp; 11Tp; 15Tp; 18tp; 21Tp; 22Tp; 26Tp; 27Tp; 28Tp; 48Tp; 49Tp; 51Tp; 52Tp; 57Tp; 58Tp; 59Tp; 60Tp; 61Tp; 66Tp; 67Tp; 73Tp; 75Tp; 78Tp; 80Tp; 81Tp; 82Tp; 83Tp; 84Tp; 86Tp; 1942.9.476
II	Wool (2Z)	Cotton (Z3S)	Cotton (4Z) (White)	R33.4.11
III	Wool (2Z)	Cotton (Z5S)	Cotton (2Z) (Light brown)	12Tp; R63.00.15
IV	Wool (3Z up to 6Z)	Cotton (Z7S-Z9S)	Cotton (1Z, 2Z, 4Z) (Pink or Beige)	26.297 53Tp; 71Tp
V	Wool (2Z)	Silk (Z2S)	Wool & Cotton (1Z, 2Z) (Beige wool & White cotton)	1942.9.477
VI	Wool (2Z)	Silk (Z2S)	Cotton (White)	26.287; T746; T747
VII	Silk	Cotton (Z7S, Z8S) (White)	Cotton (1z) (White)	26.286

Characterized by wool pile and asymmetric knots open to the left, the majority of these knots display two Z-spun yarns (sometimes 3Z or 4Z).[15] Cotton yarns in white with Z4S spin were used for the warps and 2 to 3 shoots of 2Z-spun white or beige yarn was used for the wefts (figure III. 7) inserted after each row of knots. As stated by Cohen, such qualities are consistent with classical-period Persian carpet weaving.[16] However, particular qualities were found in some of these carpets, namely, a light brown weft (carpet 1Tp), one Z-spun weft (carpets 21Tp and 67Tp), and a higher pile length for carpet 28Tp.

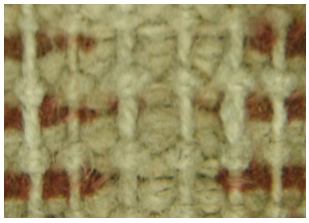

Figure III. 7: Detailed image from the back of carpet 58Tp, showing three shoots of weft yarns per row of knots (red fibers).

Groups II and VII each include a single object, and these carpets exhibit very distinct features. The carpet fragment R33.4.11 in Group II has two Z-spun wool knots (possibly two types – see appendix D), three Z-spun white yarn warps plied S and one or two shoots of 4Z-spun white yarn wefts. On the other hand, carpet 26.286 attributed to North India from Group VII, has silk knots open to the left and a cotton foundation where white 7-8Z-spun yarns plied S were used for the warp and three shoots of 1Z-spun yarn for the weft. In fact, besides the knot type and cotton foundation the features found in carpet 26.286 are not related with the standard characteristics of classical-period Persian carpets. These two carpets are considered distinctive and we will return to them later in our discussion in Chapter VII.

According to Cohen, in conventional nomenclature of structural analysis, the typical Indian warp would be described as Z6S, Z7S, or Z8S, and so on, with some cases displaying warp threads comprising up to ten to 12 cables: Z10-12S. [17] Therefore, warp yarn, in particular, can provide solid evidence of differences in Indian and Iranian carpet weaving traditions. This is particularly evident in the carpets comprising Group IV (see table III. 1), where the number of cords found in the yarn warp ranges from 7 to 9 cables – Z7S, Z8S and Z9S, strongly suggesting an Indian

[15] The S and Z letters are used to indicate the direction in which yarn(s) are twisted, spun, or plied. Thus, if fibers are spun in clockwise direction are S-spun, otherwise (counter clockwise) are Z-spun (see chapter I).
[16] Cohen, 2007b, p. 126-127.
[17] Idem, p. 126.

production. However, weaving analysis of the wefts and knots of the three objects revealed quite unique features, and thus no assumption can be made regarding their attribution. The three carpets have cotton wefts and wool knots open to the left. One carpet (71Tp) is distinguished by the presence of three shoots of 2Z-spun beige yarn wefts. The two remaining carpets (26.297 and 53Tp) display pink yarn wefts with different structures, namely, three shoots of 1Z-spun yarns in carpet 26.297 and one shoot of 4Z-spun yarns.

The most consistent is Group III where the two carpets attributed to the Deccan (India) display 2Z wool knots open to the left, 5Z-spun white yarn warps and 2Z-spun light brown yarn wefts. Finally, carpets from Groups V and VI (see table III. 1) share wool 2Z-spun knots open to the left, silk warps and cotton wefts. Group V consists of a single carpet in which Z2S silk warp yarn and three shoots of 1 or 2Z-spun beige wool and white cotton weft yarns were used.[18]

It is apparent from these results that when formulating ideas about accurate attributions, one is compelled to question the effectiveness of weaving analysis as some of particular cases cited above raise questions about whether they are mere variations of a larger group or represent an entirely different production. Therefore, a more accurate attribution of the 'Indo-Persian' carpets requires combining results from weaving, materials – fibers and dyes and designs analysis.

[18] Terminology used on technical analysis follows the work of Irene Emery, *The Primary Structure of Fabrics*.

INTRODUCTION

Carpets belonging to the so-called 'Indo-Persian' type are among the most esteemed Islamic carpets from 17th-century Europe, based on their numerous representations that survive in 16th- and 17th-century European paintings and in the inventories of the great houses of many European countries.[1] The approximately 80 'Indo-Persian' carpets extant in Portuguese collections support the perception that this carpet type was certainly being produced in great quantities.[2] Their appropriation by the state in 1834, as a result of the abolishment of the convents[3] where they had arrived during the 17th century, led to their incorporation in Portuguese public collections and, thus explains their survival in such high numbers.

With the exception of two examples (84Tp and 26.277, Appendix D) that can be linked to the aristocracy and are included in this study, the provenance of about 90 percent of these 17th century objects is well recorded. They can be associated with convents or churches where they were used in the past, although the exact date of their import is unknown.[4] Therefore, they present an exceptional opportunity to increase our knowledge about the 'Indo-Persian' carpet type, especially when compared with the small numbers of surviving carpets with 17th century provenance in collections from Europe, particularly the Netherlands[5], or elsewhere in the world.

It is known that in general these carpets share technical and aesthetic features. They are often recognized by their asymmetrical wool knots that open to the left and their cotton warps and wefts. Likewise, they feature motifs such as palmettes, Plane tree leaves (Pers. *Chenar*), lotus flowers, horseshoe-shaped and undulating cloud bands in red background fields, with blue or green background borders displaying palmettes facing inwards and outwards in a particular rhythm.

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[1] Mills, 1975; Mills, 1978; Mills, 1983; Mills, 1988; Ydema, 1991; Hallett and Pacheco, 2007.

[2] Hallett, 2007e, p. 23: "Yet their enormous practical, aesthetic and symbolic functions, knotted-pile carpets have always been luxuries, for their manufacture requires considerable organization, numerous resources, special skills, and substantial amount of time"; Pereira, 2007, pp. 19-20

[3] Pereira, 2007, pp. 35

[4] The 'Lafões' and 'Vine scroll' carpet with unidentified coats of arms. Please see carpet 26.277 and 84Tp, respectively in Appendix D.

[5] Hallett, 2007c, p. 89.

On the basis of their design, 'Indo-Persian' carpets are found in literature under different designations such as 'vine-scroll', 'scrolling-Vine-and-Blossom' or 'in-and-out palmette'.[6] In addition to this classification, further labels such as 'Herat' or 'Isfahan' formed from various assumptions regarding place of production were attached without scholarly consensus.[7] The carpet structure and color are suggestive of Iran as their place of origin, yet no historical information to directly support such an attribution has been found.

Moreover, as stated by Thompson, "carpets using a similar colouring and decorative scheme, perhaps influenced by Persian carpets, were made in India during the seventeenth century, (…)".[8] Indeed, the idea that carpet-making was being introduced to India by Persian weavers during the reign of Akbar (r. 1542-1605) comes from his Chief Minister who, in his chronicle of the Emperor's reign*, the A^{c}in-i Akbari,* describes "how His Majesty has caused carpets to be made of wonderful varieties and charming textures; he has appointed experienced workmen, who have produced many masterpieces. (…) All kinds of carpet weavers have settled here and drive a flourishing trade. They are found in every town but especially in Agra, Fathepur and Lahore*".*[9] Consequently, the origin of 17th-century 'Indo-Persian' carpets has been largely debated over the last several decades. This study focuses on an attempt to resolve their origin and therefore will maintain the generic term 'Indo-Persian' throughout until a clear nomenclature is defined to classify the group.

As for their date, there is a generalized acceptance that their production arose in the late 16th or early 17th century based on evidence from European paintings. In Portugal, this new wool carpet type began to appear in significant numbers, especially in the early 17th century, in parallel with a major shift in Iranian textile production.[10] In the late 16th century, Shah Abbas (r. 1587-1629) re-established a court library where the artists began to generate a new decorative style of floral and foliate decoration.

[6] Gans-Ruedin, 1978, pp. 94, 98-99; Spuhler, 1987, p. 74; Walker, 1997b, p. 57; Hallett, 2007c, pp. 89-91.
[7] Pope, 1926, pp. 53-55; Dimand, 1972, p. 260; Walter, 1978, p. 159.
[8] Canby, 2009, p. 210.
[9] MacAllan, 1993, p. 107; Walker, 1997, p. 7.
[10] "The revolutionary nature of these new floral designs and their sheer beauty made them highly-prized imports" in Hallett, 2007b, p. 79.

This new Safavid style aligned well with the Shah's taste and political strategy. As a bold and effective message of power, this new aesthetics was implemented across a wide range of arts. In contrast with previous periods, the design elements are larger in scale, bolder in form and more homogeneous. The same distinctive kind of split-leaf arabesque can be found in bookbinding, architectural tiles, textiles and carpets.

Shah Abbas promoted the trade of luxurious silk textiles for export.[11] Given that the 'Indo-Persian' carpets share design elements from the Abbas style, they have often been associated with this moment in Iranian production. Owing to their aesthetic features and precious materials (silk) most 16th and 17th-century Safavid carpets were only within reach of the elites in Iran and Mughal India, belonging to the court or religious circles, and some European nobility. The manufacturing features of the 'Indo-Persians' by contrast suggests an interest in decreasing the production costs, while producing quality carpets with large dimensions that were well suited to the needs of elites. They were produced using wool knots and a cotton foundation instead of silk decreasing production costs. In addition to the use of less expensive materials, they display lower knot density and fewer colors, cost-saving features that made them competitive products in international markets.

The new designs of 'Indo-Persian' carpets seem to have been intended to meet the demands of international taste, and their materials and technique made them more accessible to a wider range of consumers.[12] The outcome triggered an increase in their competitiveness in comparison to the Ottoman equivalent (made exclusively of wool). It seems apparent that these 'Indo-Persian' carpets were a commercial response to the rise of international trade, and that their predecessor are found in Iran. This dissertation looks at what motivated these changes and how and where their production developed.

The 'Indo-Persian' carpets were certainly symbols of enormous prestige. They were well matched to the requirements of the Portuguese market with its interest in high quality carpets that could reach large dimensions. In Portugal, Iberian and Turkish carpets were the dominant carpet types and the first Iranian carpets only appear in

[11] Ferrier, 1973, pp. 38-40; Floor, 1987; Ferreira, 2011, p. 11; Brancaforte and Brentjes, 2012, p. 66.

small numbers in the 16th century (i.e. 'Small silk Kashan' and 'Tree and Animal' carpets, both made using expensive silk). The rise of the Indo-Persian type in apparently the late 16th or early 17th century reflects a change in production and consumption. The reasons for the arrival of this new carpet in such large numbers appears to be related to the growing bourgeoisie in Portugal who were interested in high quality exotic products at this time, but the precise origin of their production or how they became so widespread remains to be understood.

The rise of the 'Indo-Persian' type is a defining moment that can be used to understand how Iranian and Indian carpet production adapted and responded to the demands of new markets and consumers, particularly those in Europe. Yet while this increase in production of carpets for export has been recognized in the literature, the precise mechanisms behind the increased production remain to be well understood.

This thesis argues that the so-called 'Indo-Persian' type is a commercial response from the Islamic carpet industry to new markets that result from the new maritime trade and the increase in demand for luxury goods from European elites. Consequently, an interdisciplinary approach – Art History, History and Materials Science – focusing on the study of the art historical and historical contexts surrounding their production and consumption, as well as a close analysis of stylistic features, decorative materials and technical components, supported by science, as a complementary tool for assessing the spatial and temporal dimensions of their production, is required.

The information obtained using these methods is combined to define sustained criteria for establishing groups of carpets within the so-called 'Indo-Persian' carpets. In addition, it uses the extant objects and carpet depictions to recognize the design evolution of this particular carpet type. The results aim to determine: 1) if the development of the 'Indo-Persian' carpets between the 16th and 17th centuries was a response to international trade, 2) if analysis of materials and design can be used to understand the context of production and therefore the origin of the type and 3) if the manufacturing practices were influenced by new demands.

Such abundance of resources is addressed and investigated in the following chapters. Chapter I – Historical Background, explores the complex political, economic

and cultural background that set the stage for carpet industry innovations and the subsequent development of the new carpet type. Chapter II – 'Indo-Persian' Carpet Type presents detailed characterization of the type as well as the objects included in this study. Chapter III – Fibers and Technique and V – Colors and Dyes present and combine results from fiber, technique and dye analysis to achieve a more detailed understanding manufacturing process of the 59 carpets in this study, and hence, their attribution to possible production centers. The detailed study of 'Indo-Persian' carpet designs to trace the evolution of the type and their dating to develop a chronology of production are presented in Chapters IV – Designs and VI – Dating, respectively. In the last chapter, Chapter VII - Production and Consumption, a discussion of all the results obtained is presented as it pertains to the role of the producer and consumer.

In addition to offering new and broader insights to the understanding of such a problematic type, the methodology used in this study offers a tool to public and private institutions worldwide housing 'Indo-Persian' carpets. Moreover, it explores ways to approach similar challenges presented by other historical textile collections and traditions.

CHAPTER IV

DESIGNS

Until now attempts to classify carpets have frequently been built on the assumed regions of origin or, alternatively, on systems based on visual design or artistic style, mode of production, or structure.[1] In this chapter we focus on design with some reference to fibers used in pile and foundation of the carpets.

The 'Indo-Persian' carpet type is generally characterized by the distinctive design scheme display of palmettes, chenar leaves, lotus flowers, horseshoe-shaped clouds, all intertwined with layers of vine-scrolls on a red field, surrounded by blue or green borders. The variations in design compositions underline the remaining challenges for understanding the 'Indo-Persian' type. The comprehensive study of these elements through the corpus of the carpets in this study offers a window onto how Iranian and Indian carpet production developed and adapted to accommodate the demands of new markets and consumers in places like Europe during the second half of the 16th and 17th centuries. Focusing on the 59 carpets, features such as motif, pattern, composition, style and color are all integrated in the study of design presented here.

This chapter seeks to provide a comprehensive study of their style, and possible progression, by discussing aspects of their design. It begins by defining the individual motifs found in the different elements of the carpets (i.e. in the field, major and minor borders). Then, based on the study of these elements, it looks at field designs to estimate a relative chronology. Finally, it analyses the various combinations of their fields with the major borders to establish carpet groups reflecting distinct productions. These groups are then tested in other chapters in association with further results from color and dyes, and date.

[1] Eiland, 1976; Cohen, 2003; Cohen, 2007b; Thompson, 1993; Erdmann, 1970; Ford, P. R. 1981.

IV. 1. Progression of style

In recent years carpet scholars have attempted to overcome the difficulties of classification by using technical and design analysis[2], without significant success, and the challenges to properly classify 'Indo-Persian' carpets remain. The first approach to understand the 'Indo-Persian' carpet group in Portuguese collections was proposed by Jessica Hallett, while trying to understand the transformation in Iranian carpet design at the end of the 16th and beginning of the 17th centuries, by looking at groups such as the silk 'Kashans', 'Tree and Animal' carpets (16th century) (see figure IV. 5) and the 'Indo-Persians' (17th century) (Appendix C, figures 1-3). Progression in design between these three groups is observed in the elimination of central and quarter medallions as well as animal representations; instead, in the latter group only very occasionally are birds seen in the borders. It is interesting to look more closely at this evolution to understand how Iranian carpet production in the 17th century developed by adjusting not only the choice of materials but also the designs.

The first 16th-century group, small and large silk 'Kashans', involves carpets with silk in the pile and foundation, with displays of medallions and animals in their fields and borders. In 1961 Kurt Erdmann made the first summaries of known examples attributed to this group in his book *Seven Hundred Years of Oriental Carpets* in which he describes them as: "the small silk carpets of Kashan, which are among the most important of the sixteenth-century rugs of Persia, form a clearly defined group".[3] Subsequently, this list has been extended by Daniel Walker to comprise sixteen carpets.[4] Although Kashan was an important center for the production of silk carpets,[5] no evidence has come to light to securely attribute these particular carpets to the city of Kashan, and thus, more investigation is necessary to determine which carpets can be determined to have been

[2] Cohen, 2007b; Hallett, 2007c.
[3] Erdmann, 1970, p. 61.
[4] Walker, 1994, pp. 105.
[5] "Kashan rugs acquired by the Polish king in 1602 were described as pairs, and the sill and metal thread 'Polonaise' carpets produced in Esfahan and Kashan from about 1600 on, survived in numerous pairs" in Walker, 1994, p. 106

made there. Nevertheless, Erdmann's idea that they were made in Kashan is continuously repeated.[6]

Following the Iranian carpet tradition, the second 16th-century group 'Tree and Animal' (Appendix C, fig. 2) can be characterized by botanical motifs with animal combat scenes. Where mythological creatures *bixies* and *quilin*[7], leopards, lions or deer are displayed among a profusion of trees and branches, set above a complex net of vine scrolls.[8] Throughout the latter group, the central and quarter medallions and animal representation seen in the first are significantly reduced; although occasional birds are seen in the borders between dense foliage.[9] Furthermore, the central and quarter medallions and/or animal fields are found with borders decorated by cartouches alternating with lozenges in the 'Shah Sulayman Tabriz hunting carpet with medallion' (figure IV. 1) or continuous meanders supporting large inward-and-outward-facing palmettes seen in the **'**Medallion and Animal' (figure IV. 2).

Figure IV. 1: 'The Shah Sulayman Tabriz hunting carpet with medallion', Tabriz, early 17th century. Doha, Qatar, Museum of Islamic Art, no. CA16.

[6] Erdmann, 1970, p. 61.
[7] Hallett, 2007c, p. 82.
[8] Hallett, 2007c, p. 82; Klose, 2011, p. 78.
[9] Klose, 2011.

Figure IV. 2: 'Medallion and Animal' carpet, Isfahan, early 17th century. Washington DC, National Gallery of Art, no. 1942.9.477.

Using both real objects from Portuguese collections and pictorial sources, Hallett recognized four design types within this third group of 17th-century 'Indo-Persian' carpets (Appendix C, fig. 3). By means of analysis of their field and border designs, three of these types are suggested to reflect a progression in style, while a fourth is defined to be a distinctive group (Appendix J).[10] The first carpet type (Appendix J, fig. 1) maintains the network of scrolling vines without animal or human figures, yet on occasions birds can be found. The level of sophistication of these designs means that it cannot have been rendered from memory and must have been made with reference to a design or plan. These designs may have been originated in a court context and then been disseminated to weavers who replicated them (or versions of them) in carpet workshops. The high quality of this first group can also be recognized from their material and technical features, which often include a silk warp and high knot density.

The second type can be understood as the classical 'Indo-Persian' type, in which large palmettes, cloud bands, plain tree (pers. *chenar*) leaves and lotus flowers are joined by scrolling vines (Appendix J, fig. 2). Due to the design and rhythm created by the horizontal and vertical palmette displacement, the type has been named 'vine scroll and palmette' by Hallett. Palmettes can also be found in their border pointing inward and outward. This relationship with the previous type is based on its high knot density and

[10] For further information: Hallett, 2007c.

well-planned designs in which small asymmetrical 'S'-shaped cloud bands and bigger horseshoe-shaped clouds are displayed.

In the third type 'vine scroll and curved sickle leaves' the range of motifs is increased in both the field and borders; large sickle leaves, lotus palmettes, pin-wheel rosettes, quatrefoils, horseshoe-shaped clouds and a variety of flowers are incorporated, while the plain tree leaf (pers. *chenar*) is absent (Appendix J, figure 3). According to Hallett "this diversity may reflect several independent or overlapping workshop traditions which have yet to be properly distinguished".[11]

Finally, the fourth type moves away from the previous types, as its design is not based on a scrolling vine network but instead on a lattice: 'quatrefoil Arabesque split-leaf lattice' (Appendix J, figure 4). Arabesque split-leaf motifs are arranged in quatrefoil schemes, which are organized in rows or diamond lattices. In fact, arabesque split-leaf, pomegranate palmettes, cypress trees and blossoming branches found in the fourth type appear to replace the palmettes or lotus palmettes seen in the second and third types.

In all four types the precision of their designs is noticeable in the large palmettes exhibited in the corners of the carpet, which are difficult to plan and suggest that these objects were produced in a context in which production was controlled by a skilled administration interested in following court fashions. Despite their recognizable quality, carpets belonging to the 'Indo-Persian' type are not as luxurious as the carpets being produced by the Safavid court workshops. The fact that 17th-century Iran was producing a new affordable type of carpet for new consumers suggests that carpets with animals and birds, such as the 'Kashan' and 'Tree and Animal' types, and 'Indo-Persian' groups, might represent two distinct moments in the history of Iranian carpet industry; expressing a transition in style in which a new type of carpet - for export – was developed. The following section considers how we can read carpet design to begin to understand this progression of style and production.

[11] Hallett, 2007c, p. 90.

IV. 2 Reading carpet design

Design can be perceived as both a process and as a physical entity, consisting of a complex amalgam of factors and meanings coming together in physical form at a particular place and time.[12] In light of contemporary theories, the material object provides a distinct point of entry at the physical level where the encounter between theory and practice actually occurs.[13] However, thinking about historical objects, and particularly 16th- and 17th-century carpet production, it is essential to take into consideration the context of production and patterns of consumption.

The design changes occur as a result of modes of transmission, either from one generation to the next or between social-cultural environments.[14] Thus, the role of the court and its bookmaking workshops (pers. *Kitabkhana*) in creating and disseminating designs (originally conceived for the two-dimensional surface of a folio), and their application to other media and in other circumstances outside of the court environment is of extreme relevance to the creation of sophisticated designs in carpets production. Moreover, as carpets were trade products their appreciation by consumers could encourage the development of particular designs, at the expense of others, thus influencing their diffusion. This process can involve either: a) altering particular motifs but preserving the traditional designs composition, or b) by creating new design compositions using traditional motifs, according with different skills, tastes and demands.

Stone defines carpet design as "the overall composition of decorative elements of a rug. The ornamental aspect of a rug or textile consists of lines and/or colored areas. These make up images or patterns intended to be visually pleasing or symbolic. A design may consist of an arrangement of motifs".[15] When looking at carpets this study begins by considering the motifs, followed by the composition of their overall design. Motifs are considered the dominant or distinctive elements or figures in a carpet or weaving.[16] Their

[12] Walter, 1989.
[13] "In locating design as part of a technical, commercial, professional and political process, the focus of analysis can range from design theories to manufacturing and distribution, to institutions of design such as trade organizations, educational establishments, government-funded advisory bodies, private and public consumer protection societies, to the life experience of individual designers, manufacturers and consumers" in Attfield, 1999, p. 5.
[14] Thompson, 1993.
[15] Stone, 1997, p. 63.
[16] Stone, 1997, p. 150.

compositions are generally geometric or curvilinear and displayed in the field and border, as vital elements in the overall design. The existence of elements such as quarter plans, medallions, together with certain motifs and colors, are often used to describe carpet composition and style.[17]

In addition, the way carpet was projected to be seen had great influence on its design. The approach taken here allows for the classification of carpets into two major categories: firstly, objects in which the design was planned to be viewed from a specific viewpoint which are referred to as directional, such as prayer carpets (Appendix C, figure 4), and secondly, objects that display widespread repeated motifs in which the design is non-directional (Appendix J, figure 4). Within these two broad categories, fields are often classified as single or multiple medallions, all-over repeat, vase, compartment, garden, pictorial, prayer and empty field. Likewise, main borders can be classified as meander, reciprocating, rosette, palmette and cartouche.[18]

Design studies are carried out with the aim of: 1) dating different types of carpets, as in the case of Onno Ydema, who develops an extensive inventory of carpets depicted in Netherlandish paintings[19] using their fields and borders, and 2) establishing origin as seen in a study by Jessica Hallett, who likewise explores the study of field and border designs for matters of date but additionally also for origin.

Unfortunately, published carpet design studies are often largely focused on field design. With the exception of the work of a few researchers[20], border designs are frequently disregarded. Understanding whether the borders from 'Indo-Persian' carpets were customized, and can therefore function as workshop signatures that could identify specific manufacturers, and thus origin, is one of the major aims of this study.

This project started addressing this matter by focusing on distinguishing design features from carpets belonging to the 'Indo-Persian' type discussed in Chapter II (figure II. 12). Designs seen in these carpets follow the quarter plan model (figure II. 13) with rectangular compartments mainly filled with floral motifs and clouds (see table II. 1). The result is a non-directional composition where rectangular compartments (figure II. 14)

[17] In Pearsall J. and Trumble B. (eds.), pg. 1435: "n. 1. a kind or sort, esp. in regard to appearance and form (*an elegant style of house*). (…) 6. a particular make, shape, or pattern (*in all sizes and styles*). (…)".
[18] Beattie, 1972; Erdmann, 1970; Spuhler, 1987; Stone, 1997; Klose, 2010; Denny, 2014;
[19] Ydema, 1991.
[20] Hallett, 2007c; Klose, 2010; Klose, 2011; König, 2012; Denny, 2014.

display mirror images along the vertical and horizontal axis, densely decorated with the various motifs. The graceful curves and flowing patterns seen in the field and borders are part of complex but balanced compositions. But how was the design transmitted between artists and weavers and even possibly between workshops?

It is important in this context to remember that artists and weavers would work separately to create carpets. This division of artistic labor is likely seen in two kinds of carpets production: that of court and urban carpets, both produced in urban environments, but with different relationships between investment, production and the intended consumer. Court carpets are produced in court ateliers using very expensive and luxurious and materials such silk, metal threads and wide range of colors that include expensive red-insect dyes. Moreover, their designs are often dense, intricate and sophisticated compositions, often including animals and human figures or medallions in their aesthetic vocabulary. On the other hand, carpets produce in a urban workshop are carpets of quality that can include the use of expensive materials and follow closely the sophisticated designs that are develop by artists in court ateliers, often launching the fashion applied in various art forms. These quality carpets were produced by well-equipped workshops, often with the support of the court, capable to produce in large numbers and in various dimensions, thus, responding to higher demands. Certainly, carpets manufactured in urban settings were likely to be produced in accordance with prevailing taste envisioning the creation of profitable products in the market.

According to Thompson "the workshop or town carpet as it is often called is almost by definition woven from a cartoon. The art of the carpet is therefore the art of the designer".[21] Moreover, Denny clarifies that in the creation of commercial carpets "an entrepreneur usually provides a design for the weaver to execute; owns the loom and raw materials; pays a monetary wage or piecework rate to the weaver and to the designer; and takes responsibility for the sale of the finished product, hopefully at a handsome profit to the entrepreneur". [22]

[21] Thompson, 1993, p. 135.
[22] Denny, 2014, pg. 42.

Given the sophisticated designs of the classical 'Indo-Persian' carpet, it is unlikely they were being crafted exclusively from memory. Therefore, the use of a model[23] or knot plan (*talim*) seems the most likely way for transmission of designs. It is comprised of traditional design elements and is a practice that can be passed down through generations (see Chapter II). A knot plan is intend to be respected by the weaver without deviation and requires some level of organization and skills and thus is more commonly used in urban and court workshops.[24]

Knotted-carpet weaving is a long-standing tradition in which under normal circumstances incremental design changes occur with time as a result of different ways for transmission of designs.[25] Furthermore, the actual process of replication leads naturally to a degeneration of design elements and consequently an evolution of style (see Chapter II).[26] Most notably, curvy lines in motifs and other design features lose their fluidity and sophistication, characteristic of earlier compositions (figure IV. 3), and can progress towards more geometric designs with angled or pixelated lines (figure IV. 4).

Figure IV. 3: Example of chenar leaf displayed diagonally between lotus flowers.

Figure IV. 4: Example of chenar leaf displayed in parallel to two lotus flowers.

Consequently, the ability to read Islamic carpet designs requires understanding the historical process of 'stylization'[27] in which complex designs typically based on nature are transformed into a "conventional non-realistic style" and repeated.[28] Hence, in a first stage of this study, several field and border designs were recognized on the basis of extensive

[23] Idem, p. 42: "(…) sometimes one in the weaver's own tradition, learned from a mother or grandmother. Other times, however, the entrepreneur may choose an example of a design that he feels will sell well in a projected market, European and South-East Asian markets, whether or not it belongs to the weaver's tradition."
[24] Thompson, 1993, p. 83: "*The Talim records the sequence of colours in each row of knots";* Ellis, 1988.
[25] Thompson, 1993; Franses, 2008, p. 80.
[26] Ellis, 1988, p.15.
[27] "Stylized (…) paint, draw, etc. (a subject) in a conventional non-realistic style" in Pearsall J. and Trumble B. (eds.), *Oxford English Reference Dictionary*.
[28] Denny, 2014, p. 45; Pearsall J. and Trumble B. (eds.), p. 1436.

stylistic analysis from extant carpets.[29] The second stage combined the field and major border design types together to reveal different groups of carpets (see section IV. 6), which can be used to improve the understanding of a chronological evolution and context of production (court, city, etc.), for tackling questions regarding the geographic location for their production.

A survey of all the carpets included in this study is undertaken to determine several types of fields, and major and minor borders (see sections IV. 3. and IV. 4). The system to distinguish field and border types is represented using uppercase letters for fields (e.g. A or B) and lowercase letters for borders (e.g. a or b), and then numbers are used to differentiate individual types of field and border designs (e.g. A1 or A2 for field). The final letters and numbers presented were attributed after the full analysis was undertaken in order to facilitate the reader's understanding of the design evolution observed.

This survey revealed that, in addition to the four motifs commonly found in the fields of carpets under the 'Indo-Persian' designation (see table II. 1), eight new motifs were identified (see section IV. 5). These were found to be noteworthy elements for considering issues of origin or chronology.

IV. 3. Field designs characterization

In the current study the four design types identified as representing a progression in the development of the 'Indo-Persian' group described above[30] are expanded to seven major fields: *Field A - 'Tree and Animal'; Field B – 'Vine scroll with Central Medallion'; Field C – Vine scroll with Central Void and Clouds; Field D – Vine scroll with Central Void and Clouds - Sickle leaf; Field E – 'Tile Pattern field'; Field F – 'Tile Pattern – Quatrefoil Arabesque split-leaf'* and *Field G – 'Large-scale geometrical networks of Vine scroll and Sickle leaf'*.

Moreover, with the aim of following the evolution of design, this study includes earlier carpet types, such as the 'Medallion and Vine scroll' or 'Animal and Vine scroll' and 'Animal and Tree' carpet types believed to date from the second half of the 16th century.[31] Accordingly, *Fields A* and *B* illustrate examples of earlier designs, and in which

[29] Ydema, 1991.
[30] Hallett, 2007c, p. 90
[31] Hallett, 2007c, p. 90

silk warps are still seen as part of the foundation, preceding the so-called 'Indo-Persian' type with cotton warps and wefts. For each of the seven field types, their motifs, composition and materials are listed below, along with an illustration. This is followed at the end by a discussion on the different combinations of fields and major border designs. .

Field A - 'Tree and Animal'

The Field *A 'Tree and Animal'* (attributed to 16th century) represented in this study by a single carpet exemplifies a progression or variation of the '*Medallion and animal'* design in figure IV. 2 (see Appendix C). The center and quarter medallions in the corners presented on a red saturated ground disappear here. Instead, small-scale motifs or voids replace them and design compositions with floral and animal motifs in Field A. Moreover, they display silk warp, cotton wefts, wool knots and a large color palette, between twelve and eighteen hues. Also, small-scale motifs and a dense and sophisticated net of vine-scrolls characterize this field design.[32]

Motifs: Animals, trees, horseshoe-shaped clouds, *tchi* clouds, palmettes, chenar leaves, lotus flowers. Two sets of vine-scrolls with different colors.

Composition: Diagonal chenar leaves facing inwards, palmettes and horseshoe-shaped clouds on both sides along the carpets vertical axis (Figures IV. 5 and IV. 6). Two dense and delicate sets of vine-scrolls decorated with small flowers and buds. The small-scale curves and motifs are exquisitely drawn .

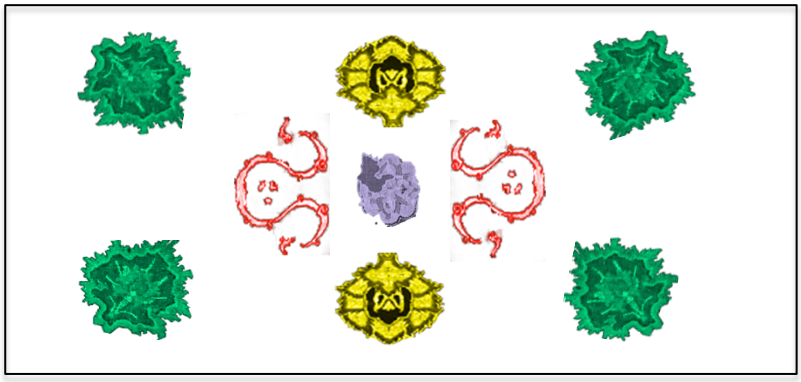


Figure IV. 5: Field composition scheme of 'Tree and Animal' carpet – Field A. Depicting motifs most commonly found in carpets belonging to 'Indo-Persian' group.

[32] For additional information see: Klose, 2011, pp. 76-85.

Figure IV. 6: Field (detail) of 'Tree and Animal' carpet (Large fragment), Iran (?), late 16th to early 17th century. Lisbon, MNAA, 47Tp.

Field B - 'Vine scroll with Central Medallion'

Likewise, the use of silk and cotton in the foundation and wool knots as well as the central design composition are maintained in Field B, represented here by a single object (figure IV. 6). However, the field design manifests a significant change as figures of animals and/or trees disappear from the vocabulary.

Motifs: Horseshoe-shaped clouds; two types of *tchi* clouds; chenar leaves; lotus flowers. Two set sets of scrolling vines (two colors).

Composition: Medallion cartouche in the center surrounded by Arabesque split-leaf and symmetrical composition along the vertical axis (Figures IV. 6 and IV. 7). Two sets of dense and delicate scrolling vines, with different, colors decorated with small lotus flowers, rosettes and buds. The curves are beautifully drawn with smaller scale motifs.

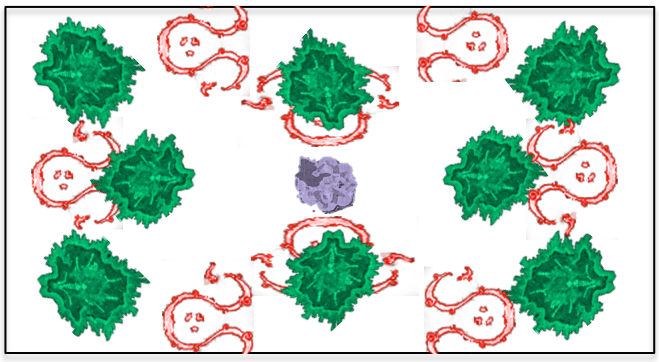


Figure IV. 6: Field composition scheme of 'Vine scroll with Central Medallion' carpet – Field B

Figure IV. 7: Field (detail) of 'Vine scroll with Central Medallion' carpet, Iran (?), late 16th to early 17th century. Coimbra, MNMC, T746.

Field C0 – Vine scroll with Central Void and Clouds

Field *C0* represents the early version of Vine scroll with Central Void and Clouds field design. Exhibited by two objects (figures IV. 9 and IV.10) in which silk warps were use in the foundation just as seen in the previous designs, Fields A and B. However, the central medallion is replaced by a void, while the two sets of vine scrolls take a progressively bigger role in the overall field rhythm and composition. The chenar leaves are emphasized and their placement facing inwards alternates with outwards facing palmettes along the symmetrical vertical axis.

Motifs: horseshoe-shaped clouds; *tchi* clouds; palmettes, chenar leaves; lotus flowers. Two dense and delicate sets of vine-scrolls decorated with small flowers and buds. The high-quality curves are drawn using smaller scale motifs.

Composition: Chenar leaves facing inwards, palmettes and horseshoe-shaped clouds on both sides along the carpets vertical axis (Figures IV. 8 and IV. 9)

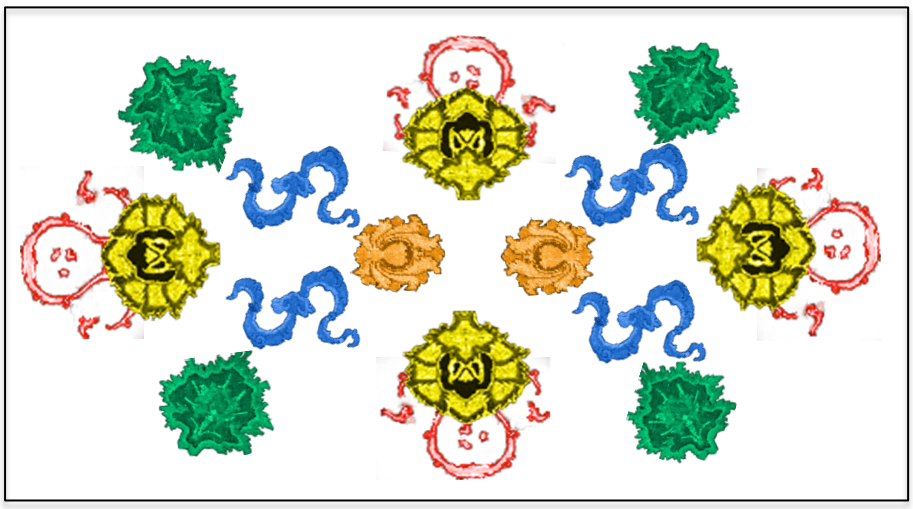


Figure IV. 8: Field composition scheme of '*Vine scroll with Central Void and Clouds*' carpet – Field C.

Figure IV. 9: Field (detail) of '*Vine scroll with Central Void and Clouds*' design carpet, Iran (?), late 16th to early 17th century. Coimbra MNMC, T747.

Carpet 26.287 (figure IV. 10) seems to be an exception within Field C0 (*'Vine scroll' design – lotus flowers*). The rhythm and composition are maintained but instead of inwards facing chenar leaves; lotus flowers take the stage as predominant element in the field. No clouds of any style can be seen in the field. Furthermore, a cartouche border is shared with Field B, a matter to be discussed later in this study, suggesting that this object might embody the transition in style and materials seen in the previous Fields A and B to Field C.

Motifs: Larger scale motifs such as palmettes, chenar leaves, lotus flowers and rosettes. One dense vine-scroll decorated with lotus flowers, rosettes and buds.

Composition: Palmette facing outwards at the center and along the vertical axis on both sides of the carpet. One dense vine-scroll decorated with lotus flowers, rosettes and buds.

Figure IV. 10: Field (detail) from '*Vine scroll and lotus flowers'* carpet (*Esfahan Herat*), Iran (?), 16th century (?). Whereabouts Unknown (Ex. Corcoran Gallery of Art, 26.287).

Field C1 - Vine scroll with Central Void and Clouds – Palmettes

This field design is represented by two objects, which maintain the use of wool knots but where silk warps were replaced by the exclusive use of cotton in the warps and wefts. Both carpets (figures IV. 11 and IV. 12) have large dimensions (more than 4 meters long) and displaying large palmettes facing in-and-out along vertical axis and the inclusion of new elements such as the coat of arms or variation in the traditional background color scheme (figure IV. 12). The green field in carpet 84Tp represents an outstanding exception to the red field typically seen in carpets. Together the characteristics suggest that both objects may have been special commissions.

Motifs: Horseshoe-shaped clouds; *tchi* clouds; palmettes, chenar leaves; lotus flowers; two dense and delicate vine-scrolls decorated with small flowers and buds.

Composition: In-and-out arrangements of Palmettes along the vertical axis, palmettes and horseshoe-shape clouds on both sides along the carpets vertical axis (Figures IV. 11 and IV. 12). The curves are beautifully drawn with small-scale motifs in large dimensioned carpets.

Figure IV. 11: Field (detail) from '*Vine scroll with Central Void and Clouds – Palmettes'* carpet (*'Vine scroll' Carpet*, Large fragment), Iran (?), 17th century. Lisbon, MNAA, 15Tp.

Figure IV. 12: Field (detail) from '*Vine scroll with Central Void and Clouds – Palmettes'* carpet (*'Vine scroll' Carpet*, Large fragment), Iran (?), 17th century. Lisbon, MNAA, 84Tp.

Field C2 - Vine scroll with Central Void and Clouds – Chenar leaf

Observed in eight carpets Field C2 is a variation that appears to progress from C1 as it maintains the use of cotton warp and weft, and wool knots. The scale of motifs increases, while the precision and elegance of diagonal lines decreases, along with the knot density. These three features are in keeping with a decrease in production time and costs.

Motifs: Horseshoe-shaped clouds; *tchi* clouds; palmettes, chenar leaves; lotus flowers; 2 dense vine-scrolls decorated with small flowers and buds. Large scale motifs in carpets with smaller dimensions.

Composition: Chenar leaves facing inwards along the vertical axis with palmettes and horseshoe-shaped clouds on both sides of the carpet (Figures IV. 13, IV. 14, IV. 15 and IV. 16).

Figure IV. 13: Field (details) from '*Vine scroll with Central Void and Clouds – Chenar leaf*' carpet (*Carpet with pattern of scrolling vines*), Iran (?), 17th century. Coimbra, MNMC, T748.

Figure IV. 14: Field (detail) from '*Vine scroll with Central Void and Clouds – Chenar leaf*' carpet (*Carpet with pattern of scrolling vines*), Iran (?), 17th century. Lisbon, MNAA, 10Tp.

Figure IV. 15: Detail of half design seen on the field of a '*Vine scroll with Central Void and Clouds – Chenar leaf*' carpet (*Carpet with pattern of scrolling vines*), Iran (?), 19th century (?). Lisbon, MNAA, 27Tp.

Figure IV. 16: Field (detail) from *'Vine scroll with Central Void and Clouds – Chenar leaf'* carpet (*Carpet with pattern of scrolling vines,* Fragment), Iran (?), late 17th and 18th century (?). Coimbra, MNMC, T750.

Field C3 - Vine scroll with Central Void and Clouds – Outward Palmette

The replacement of inward-facing chenar leaves by outwards facing palmettes lying symmetrically along the vertical axis can be seen in six objects with field C3. While the choice of fibers was maintained, it is noteworthy that the particular transformation observed here, as in all the fields discussed previously, involves a pattern in which the creativity occurs initially in the field design and progress to the border reinforcing the sequencing of the different types here.

Motifs: Horseshoe-shaped clouds; *tchi* clouds; palmettes, chenar leaves; lotus flowers; 2 vine-scrolls decorated with small flowers. Large scale motifs. The carpet with inventory number T749 (see figure IV. 17) displays a "new" five-petal flower, which can be seen, combined with pin-wheel rosettes in other objects (see *Field C4*).

Composition: Palmettes facing inwards along the vertical axis with palmettes and horseshoe-shaped clouds on both sides of the carpet (Figures IV. 17, IV. 18 and IV. 19).

Figure IV. 17: Field (detail) from '*Vine scroll with Central Void and Clouds – Outward Palmette'* carpet (*Carpet with pattern of scrolling vines*), Iran (?), 17th century. Lisbon, MNAA, 73Tp.

Figure IV. 18: Field (detail) from '*Vine scroll with Central Void and Clouds – Outward Palmette'* carpet (*Carpet with pattern of scrolling vines*), Iran (?), 17th century. Lisbon, MNAA, 26Tp.

Figure IV. 19: Field (detail) from '*Vine scroll with Central Void and Clouds – Outward Palmette'* carpet *(Carpet with pattern of scrolling vines)*, Iran (?), 17th century. Coimbra, MNMC, T749.

Field C4 - Vine scroll with Central Void and Clouds – Pin-wheel

The progressive degeneration of the Field C is expressed in the four carpets displaying C4. However, in addition to a decrease in knot density and sophistication of the design, Field C4 is also characterized by the inclusion of an entirely new motif: the pin-wheel rosette (Figures IV. 20, IV. 21 and IV. 22).

Motifs: Horseshoe-shaped clouds; palmettes, chenar leaves; lotus flowers and pin-wheel rosettes; one or two vine-scrolls decorated with small flowers and buds. Exceptions are carpets with 5-petal flowers (figure IV. 21) and without horseshoe-shaped clouds (figure IV. 22). The larger scale motifs are also found in carpets of smaller dimensions.

Composition: Palmettes facing inwards along the vertical axis with palmettes and horseshoe-shaped clouds on both sides of the carpet (Figures IV. 20, IV. 21 and IV. 22).

Figure IV. 20: Field (detail) from '*Vine scroll with Central Void and Clouds – Pin-wheel'* carpet (*Carpet with diamond medallion and pattern of scrolling vines*), Iran (?), 17th or 18th century. Coimbra, MNMC, T756.

Figure IV. 21: Field (detail) from '*Vine scroll with Central Void and Clouds – Pin-wheel'* carpet (*Carpet with pattern of scrolling vines)*, Iran (?), 17th century. Lisbon, MNAA, 2Tp.

Figure IV. 22: Field (detail) from '*Vine scroll with Central Void and Clouds – Pin-wheel'* carpet (*Esfahan*), Iran (?), 16th century (?). Whereabouts Unknown (Ex. Corcoran Gallery of Art, 26.285).

Field D0 - Vine scroll with Central Void and Clouds - Sickle leaf

The introduction of the sickle leaf into the design represents the development of a different design scheme from the carpets with Field C discussed above. This is evident in the nine objects in which the insertion of the sickle leaf permitted greater fluidity in the design.

This fluidity was gradually lost in Field C4 by decreasing the number of motifs and simplifying the vine-scroll system in order to reduce the knot count. Thus, the inclusion of sickle-leaf had a pronounced role and impact to the overall design composition of Field D0. The curvilinear shape of the sickle leaf was able to recreate fluidity seen in previous

types' compositions achievable with silk warps or a high-knot density. Such innovation represents a creative response to attempting to provide more sophisticated designs and lively compositions (see Carpet 61Tp in Appendix D).

Motifs: Horseshoe-shaped clouds, *tchi* clouds, palmettes, pin-wheel rosettes, sickle leaves, chenar leaves, lotus flowers, buds, leafs and two vine-scrolls.

Composition: Sickle leaves sinuously drawn play a main role, creating a dynamic rhythm within the various motifs displayed (Figures IV. 23, IV. 24 and IV. 25). The composition created is symmetrical along the carpet vertical axis. The pomegranate palmette is seen introduced for the first time in the field. Two vine-scrolls with the same color are decorated with smaller flowers and buds.

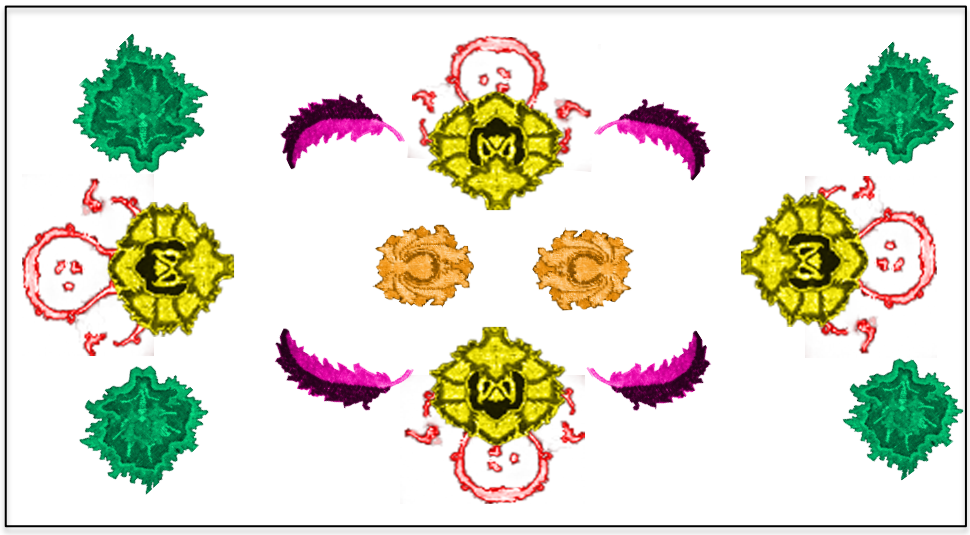


Figure IV. 23: Example of field composition scheme of '*Vine scroll with Central Void and Clouds – Sickle leaf*' carpet – Field D.

Figure IV. 24: Field (detail) from '*Vine scroll with Central Void and Clouds - Sickle leaf*' carpet *(Carpet with pattern of scrolling vines*), Iran (?), 17th century. Lisbon, MNAA, 86Tp.

Figure IV. 25: Field (detail) from '*Vine scroll with Central Void and Clouds - Sickle leaf*' carpet (*Carpet with pattern of scrolling vines*), Iran (?), 17th century. Coimbra, MNMC, T751.

Field D1 - Vine scroll with Central Void - Sickle leaf, without clouds

Field carpet D1 is present in five objects, representing a progress or variation of D0, in which the presence of sickle leaves is emphasized by the suppression of motifs such as the horseshoe-shaped cloud, which played a significant role as a major design element in the decorative vocabulary of the Vine scroll with Central Void and Clouds carpets (Field C).

Motifs: Large dimension palmettes, sickle leaves, chenar leaves, lotus flowers, bud and leafs. Two sets of vine-scrolls.

Composition: Following the classical distribution of motifs, sickle leaves were placed creating a dynamic rhythm in the field. Two large palmettes on each side of the field can be seen. The composition created is symmetrical along the carpet vertical axis. Two vine-scrolls in the same color are decorated with smaller flowers and buds (Figure IV. 26).

Figure IV. 26: Field (detail) from '*Vine scroll with Central Void and Clouds - Sickle leaf, without clouds*' (*Carpet with pattern of scrolling vines*), Iran (?), 17th century. Lisbon, MNAA, 21Tp.

Field D2 - Large-scale Vine scroll with Central Void and Clouds - Sickle leaf

Here, elements of D0 - *Vine scroll with Central Void and Clouds - Sickle leaf* are incorporated into unusual, yet intricate and elegant, compositions displaying large-scale motifs. Moreover, the level of design sophistication and large dimension seen in the single carpet displaying this field suggests a particular production setting, likely a resourceful carpet workshop. It should not necessarily be interpreted as being a later development of D0 or D1, as it could be a parallel one.

Motifs: Large dimensioned horseshoe-shape clouds, *tchi* clouds, palmettes, pomegranate palmettes, sickle leaves, chenar leaves, lotus flowers, bud and leafs. Two vine-scrolls with the same color.

Composition: Sickle leaves sinuously drawn play a main role, creating a dynamic rhythm within the various motifs displayed (Figure IV. 27). The composition created is

symmetrical along the carpet vertical axis. The pomegranate palmette is seen introduced in the field for the first time. Two vine-scrolls decorated with smaller flowers and buds.

Figure IV. 27: Field (detail) from '*Large-scale Vine scroll with Central Void and Clouds - Sickle leaf*' carpet *(Large Esfahan Herat)*, Iran (?), early 17th century (?). Whereabouts Unknown (Ex. Corcoran Gallery of Art, 26.277).

Field D3 – Large-scale Vine scroll with Central Void and Clouds - Sickle leaf, Geometric composition

Similarly to what was observed in Field D2 the two objects embodying Field D3 are of vast dimensions. However, in this case the large-scaled motifs were maintained but the sophisticated composition develops towards a more rigid and geometrical one. This effect suggests that it could be a later development after Fields D0, D1 and D2. These designs are found in large objects and appear to have been developed with the intention or decreasing cost, while enhancing the speed of manufacture, something that is also seen in the following field designs E and F.

Motifs: Large dimensioned horseshoe-shaped clouds, *tchi* clouds, palmettes, sickle leaves, chenar leaves, lotus flowers, buds, leaves and two sets of vine-scrolls.

Composition: Motifs very stylized. The composition created is symmetrical along the carpet vertical axis (Figure IV. 28). Two vine-scrolls decorated with smaller flowers and

Figure IV. 28: Field (detail) from **'***Large-scale Vine scroll with Central Void and Clouds - Sickle leaf, Geometric composition'* carpet **(***Carpet with pattern of scrolling vines*), Iran (?), 17th century. Coimbra, MNMC, T754.

Field E - Tile-pattern design

In the single object illustrating Field E it is observed that the traditional motifs presented against a red ground are preserved. Their display however was reinvented in an entirely new composition, in which they are used in repeating patterns that create a tile effect. This aesthetic solution allowed the creation of endless design variations simply by changing their color or location in the pattern. It was well suited to production of carpets of any length, which could be started and finished at any desired point. Something, which was impossible with the use of the quarter plan, as it required pre-planning and fixed final dimensions before starting the work could begin.

Motifs: Pin-wheel, Medallion cartouche, Palmette; Pomegranate palmette; Sickle leaves; lotus flowers; two vine-scrolls with a single color, decorated with small flowers and buds.

Composition: Motifs from previous types are displayed in rows, each one exhibiting different combinations of motifs (Figure IV. 29). The rectangular pattern created is symmetrical along the carpet vertical axis.

Figure IV. 29: Field (detail) from 'Tile pattern' carpet (*Carpet with lattice pattern*), Iran (?), 17th century to 18th century. Lisbon, MNAA, 81Tp.

Field F – Tile pattern design – Quatrefoil arabesque split-leaf

Field F is illustrated by three objects, all sharing with the previous field types C and D a similar choice of fibers, weaving techniques and decorative vocabulary. The motifs however are organized in a grid or lattice system against a red background. Arabesque split-leaves are arranged in quatrefoil forms organized in off-set repeating rows, replacing scrolling vines. Likewise, this solution allows the creation of endless variations of results by changing colors or motifs, and carpets of any length.

Motifs: Quatrefoil-arabesque split-leaf, sickle leaves, chenar leaf, lotus palmette, pomegranates and octafoils. One vine-scroll decorated with sprays of small flowers and buds.

Composition: Motifs repeatedly displayed in offset rows (Figure IV. 30, IV. 31 and IV. 32).

Figure IV. 30: Field (detail) from Tile Pattern' design – Quatrefoil Arabesque split-leaf (*Carpet with quatrefoil-lattice pattern*), Iran (?), 17th century to 18th century. Lisbon, MNAA, 48Tp.

Figure IV. 30: Field (detail) from Tile Pattern' design – Quatrefoil Arabesque split-leaf (*Carpet with pattern of scrolling vines and quatrefoil Arabesque split-leafs*), Iran (?), 17th century. Lisbon, MNAA, 67Tp.

Figure IV. 32: Field (detail) from Tile Pattern' design – Quatrefoil Arabesque split-leaf (*Carpet with pattern of scrolling vines and quatrefoil Arabesque split-leafs*, Iran (?), 17th century. Lisbon, MNAA, 75Tp.

Field G – Large-scale geometrical networks of Vine scroll and Sickle leaf

This group encloses carpet fragments with field designs falling outside the Fields C and D. Despite their large dimensions we are unable to fully reconstruct the pattern and establish a further classification of the field design and, therefore, only limited design analysis is attainable. Nonetheless, it is possible to differentiate various geometrical and large motifs in a degenerated style; the motifs seen in the previous types are incorporated and displayed in original compositions.

Motifs: Sickle leaves, chenar leaves, lotus palmettes, pomegranates and octafoils. Two vine-scrolls decorated with sprays of small flowers and buds. Large-scale motifs.

Composition: Symmetrical along the carpet vertical axis (Figures IV. 33 and IV. 34).

Figure IV. 33: Field (detail) from *Large-scale Vine scroll and Sickle leaf geometrical networks* carpet fragment (*Carpet with large pattern of scrolling vines,* Fragment), Iran (?), 17th century. Lisbon, MNAA, 57Tp.

Figure IV. 34: Field (detail) from *Large-scale Vine scroll and Sickle leaf geometrical networks* carpet fragment (*Carpet with large pattern of scrolling vines,* Fragment), Iran (?), 17th century. Lisbon, MNAA, 59Tp.

To summarize, analysis of the designs reveals the existence of seven fields. These appear to exhibition an evolution in design occurring sequentially from A and B to C and D, and finally Fields E and F. Field G is comprised only by fragments, thus insufficient to establish firmed a conclusion. It shows however, that the production of carpets with large-scale motifs and creative compositions were being produced.

This design evolution seems to be supported by the choice of fibers used in the knots, warps and wefts, which progresses from the use of silk in the foundations and wool in the pile of carpets exhibiting Fields A and B and C0, to exclusively cotton foundation and wool pile. Moreover, between variations of Fields C and D there are the suggestion of design evolution, beginning with a more sophisticated original design (C0 or D0) that degenerates to something with larger scale motifs and lower knot density (C3 or C4 and D3), and with the inclusion of a new motif – sickle leaf – between Fields C and D.

Finally, Fields E and F represent new design compositions that allow endless variations using the traditional motifs seen in previous types. The following sections looks into the various borders found.

IV. 4. Major and minor border characterization

As described in Chapter II, a decorated border frequently frames carpet fields'. This design is composed of three elements, i.e., major border, inner minor border and outer minor border (figure IV. 35).

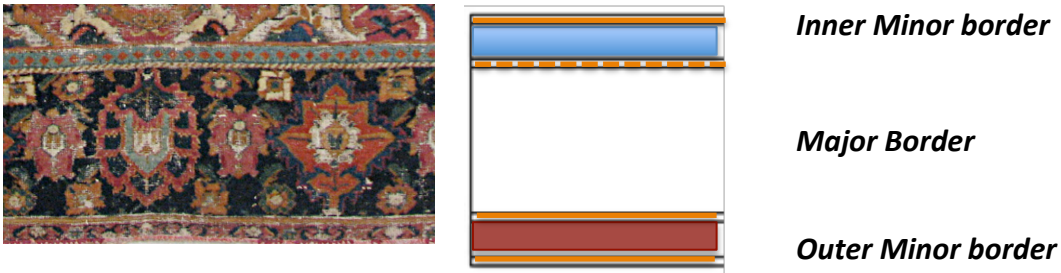


Figure IV. 35: Border (detail) with the corresponding scheme and designation of its consisting elements.

These elements can be found in combination with several guard-stripes and with different colors or motifs (figure IV. 36). The result is more intricate border design schemes. Understanding whether the borders were customized and could be use as a potential tool for determining the origins of these carpets is a major goal of this study, and recognize the existence of chronological evolution of the design from the examined real objects.

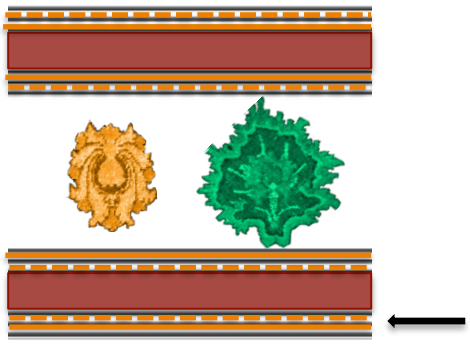


Figure IV. 36: Border (detail) with the corresponding guard-stripes illustration (indicated by the arrow).

Major Borders

Of the 59 carpets examined, thirteen major borders were identified. The composition, pattern and motifs present in the carpet designs were the major criteria to identify different borders. Illustrated descriptions are given below (table IV. 1). The first type uses geometrical components, while the following use a combination of palmettes, lotus flowers, rosettes and other floral elements arranged along an undulating vine, which is sometimes visible and other times disguised by the scale and number of motifs.

Table IV. 1: Major border design types identified in the 52 objects of Iranian attribution from this study.

Major border a - Cartouche and medallion

Figure IV. 37: Border (detail) from *Vine scroll with Central Medallion* carpet, Iran (?), 17th century. Coimbra, MNMC, T746.

Figure IV. 38: Border (detail) from *Vine scroll and lotus flowers* carpet, Iran (?), 16th century (?). Whereabouts unknown (former Corcoran Gallery of Art, 26.287).

Major border b - Arabesque split-leaf vine (alternating with lotus flower)

Figure IV. 39: Border (detail) from *Vine scroll with Central Void and Clouds - Sickle leaf, without clouds* carpet. Iran (?), 17th century. Lisbon, MNAA, 16Tp.

Major border c - Single vine meander with lotus flower and large bud

Figure IV. 40: Border (detail) from *Vine scroll with Central Void and Clouds – Chenar leaf* carpet, Iran (?), 17th century. Lisbon, MNAA, 28Tp.

Major border d – In-and-out lotus flower

Figure IV. 41: Border (detail) from *Tile Pattern* carpet, Iran (?), 17th to 18th century. Lisbon, MNAA, 81Tp.

Major border e – In-and-out palmette and lotus flower

Figure IV. 42: Border (detail) from *Large-scale Vine scroll with Central Void and Clouds - Sickle leaf, Geometric composition* carpet, Iran (?), 17th century. Lisbon, MNAA, 78Tp.

Major border f – In-and-out arrangements of palmettes and chenar leaves

Figure IV. 43: Border (detail) from *Vine scroll with Central Void and Clouds – Chenar leaf* carpet, Iran (?), 17th century. Lisbon, MNAA, 10Tp.

Major border g – Lotus flower alternating with pairs of curved sickle leaves clasping a rosette

Figure IV. 44: Border (detail) from *Vine scroll with Central Void and Clouds - Sickle leaf* leaves carpet, Iran (?), 17th century. Coimbra, MNMC, T758.

Major border h – Pairs of curved sickle leaves clasping a void

Figure IV. 45: Border (detail) from *Vine scroll with Central Void and Clouds - Sickle leaf, without clouds'* carpet, Iran (?), 17th century. Lisbon, MNAA, 21Tp.

Major border i – Double pairs of curved sickle leaves clasping lotus flower

Figure IV. 46: Border (detail) from *Large-scale Vine scroll with Central Void and Clouds - Sickle leaf* carpet, Iran (?), 17th century (?). Whereabouts Unknown (Ex. Corcoran Gallery of Art, 26.277).

Major border j - Single vine meander with rosette and bud

Figure IV. 47: Border (detail) from *Vine scroll with Central Void and Clouds –Pin-wheel* carpet, Iran (?), 17th to 18th century. Coimbra, MNMC, T756

Major border k – Pomegranate palmette alternating with cypress tree

Figure IV. 48: Border (detail) from *Tile Pattern – Quatrefoil Arabesque split-leaf* carpet, Iran (?), late 17th to 18th century. Lisbon, MNAA, 48Tp.

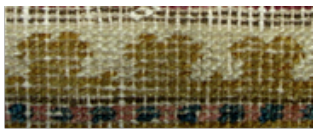
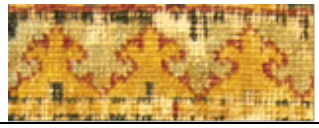
Major border l – In-and-out palmette alternating with large meander

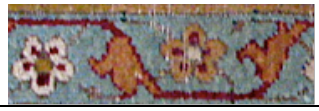
Figure IV. 49: Border (detail) from Medallion and Animal carpet, Iran (?), 17th century. Washington DC, NGA, 1942.9.477.

Minor Borders

From the survey on the thirteen major borders, 22 minor borders – inner and outer are recognized and illustrated below. The majority of the minor borders identified exhibit floral compositions, while some comprehend exclusively geometric elements. Moreover, minor borders a and b with floral elements, include vine-scrolls or clouds, thus being the most sophisticated of all.

Table IV. 2: Minor border design types identified in the 52 objects of Iranian attribution from this study.

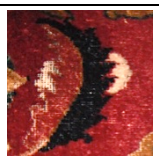
Minor border a - Meander with lotus palmette and lotus flower	
Minor border b - Lotus and *Tchi* clouds	
Minor border c - Lozenges	
Minor border d - Chevron with dots	
Minor border e - Adjacent scrolls	
Minor border f - Paired dots meander	
Minor border g - Herringbone	
Minor border h - V-shaped interlock	
Minor border I - Heart-shaped interlock	
Minor border j - Double vine Interlock	
Minor border m - Dots	
Minor border n - Vine interlock	
Minor border k - Trefoil interlock	
Minor border l - Cartouche and diamond	

Minor border o - Double arabesque split-leaf meander	
Minor border p - Single arabesque split-leaf meander	
Minor border q - Lotus flower and rosettes	
Minor border r - Double sickle leaf meander	
Minor border s - Trefoil vine meander	
Minor border t - Rosette and leaf	
Minor border u - Rosette and lotus	
Minor border v - Double meander and rosette	

IV. 5. Motif identification

In addition to the presence or absence of motifs such as horseshoe-shaped clouds, *tchi* clouds, palmettes, chenar leaves, lotus flowers, the design analysis undertaken here permitted to identified further motifs such as the pin-wheel rosettes, tile-quatrefoil, pomegranates or pomegranate palmettes, arabesque split-leaf, sickle leaves and flower sprays (Table IV. 3). The occurrence of these motifs represents major criteria to determine several types of field and border.

Table IV. 3: Motifs most commonly found in carpets belonging to 'Indo-Persian' group.

Lotus Palmettes		Lotus flower	
Chenar leaf		Horseshoe-shaped cloud	
Tchi cloud		Serrated	
Tile-quatrefoil		Arabesque split-leaf	
Pomegranate		Sickle Leaf	
Pin-wheel rosette		Flower spray	

IV. 6. Groups: Fields and Major Borders

Having identified various field and border types above, based on extensive stylistic analysis of the designs surveyed in the 59 carpets, it is now possible to undertake on the second phase of this study and begin the process of forming design groups. The occurrence of fourteen different field designs in combination with twelve major border patterns was evaluated to establish stylistic groups within the 'Indo-Persian' carpet type, and attempt to understand their relationships and possible chronological evolution of design.

The system of uppercase and lower case letters used to distinguish between fields and major border systems**,** respectively, in the analysis above is maintained here (for example, *Field A – Tree and Animal* and *Major border b – Arabesque split-leaf vine (alternating with lotus flower)*. Furthermore, variations in the fields are designated using uppercase letters (e.g. A, B, C) for the major type and numbers for each new design within

it (for example, *Variation C1 – Vine scroll with Central Void and Clouds and Variation C2 - Vine scroll with Central Void and Clouds – Chenar leafs).*

As discussed above, it is possible to seriate designs in a relative chronology based on the evidence that sophisticated curvilinear designs developed from the work of court ateliers and were interpreted over time, and in other contexts, resulting into more stylized ones. Therefore, the comprehensive study of their style begins by identifying the most sophisticated designs and is followed by looking for degenerations of them to establish a design progression, as described above. The proposed evolution of the field designs has been organized for the reader, after the complete analysis was undertaken, to follow the natural alphabetic and numeric order, i.e. carpets falling into Field A are believed to precede carpets from B and C, while carpets with variation Field C0, for instance, are believed to precede or occurs in parallel with field variation C1, C2, C3.

The major borders (and not the fields) are taken as a starting point for the discussion below, due to the occasional assumption that borders were sometimes used as workshop signatures and maintained over longer periods than field designs. They are also more often depicted in paintings and so more absolute dates can be associated with them, at a later stage of analysis (see Chapter VI).

By exploring the relationship between each border type and the field patterns associated with it, it is possible to build a relative chronology for the actual carpets and to assess the popularity of specific designs. Each major border type is used to establish a different group. To support this discussion, they are presented in individual charts with their associated field designs and objects for easy reference. Moreover, to preserve consistency, the methodology previously used in this study based on the presence or absence of certain motifs was maintained (see section IV. 5. Motifs identification). Carpets and fragments attributed to India were not included at this stage. In addition, particular attention was given to changes in the composition and design of the fields and borders to outline stylistic evolution. The '*Animal and Tree'* carpet displayed in figure IV. 50, dated to the second half of the 16th century, offers a starting point for tracing this chronology as a predecessor of later developments.

Figure IV. 50: '*Animal and Tree'* carpet fragment, 2nd half of 16th century. Museu Nacional de Arte Antiga, Lisbon.

The most popular border seen in the Indo-Persian carpets is a direct development of that seen in the Animal and Tree carpet: namely, the major border composition, referred to here as f, maintains the identical arrangement of outward palmettes and inward chenar leaves alternating with lotus flowers surrounded by pairs of smaller motifs, often rosettes or leaves, but without any representation of animal figures. Major border f is seen in 20 objects, and is associated with variations of two different fields, namely C and D (table IV. 4). These are distinguished mainly by the presence of the sickle leaf, exclusively in the latter.

Table IV. 4: Border group *f – In-and-out arrangements of palmettes and chenar leaves*

Inv. Number	Field
47TP	A
T747	C0
15Tp	C1
84Tp	"
10Tp	C2
27Tp	"
T748	"
T750	"
26Tp	C3
73Tp	"
T749	"
T753	"
52Tp	"
26.285	C4
2Tp	"

	26.300	D0
	22Tp	"
	83Tp	"
	86Tp	"
	T751	"
	T754	D3

Considerable uniformity is revealed when associating major border f with all variations of Field C. In terms of evolution, the complexity and density of the drawing seen in C0 - *Vine scroll with Central Void and Clouds* is transformed progressively into a less dense and more stylized design, which reaches its height in C4 (see section IV. 3.). This would appear to indicate that the border was maintained over some length of time as it accompanied four field variations, along with the introduction of entirely new vocabulary into the composition, namely the sickle leaf in Field D.

The presence of major border f in association with the very first and last variations of Field D, namely in *D0 - Vine scroll with Central Void and Clouds - Sickle leaf* and *D3 Large-scale Vine scroll with Central Void and Clouds - Sickle leaf, geometric composition* (see IV. 3 Field designs characterization) seems to suggest that at some point Fields C and D may have overlapped, and were produced in the same geographical space (region or workshop) and/or at the same time, something we will return to in Chapter VII.

Major border *e – In-and-out arrangements of palmettes and lotus palmettes* is displayed in two carpets belonging to Table IV. 5. It follows the general in-and-out arrangement of major border *f*, but the chenar leaf is replaced here by the lotus palmette, while the lotus flowers in between are replaced by pin-wheel rosettes or small rosettes, surrounded by pairs of smaller motifs at their corners.

Table IV. 5: Border group *e – In-and-out arrangements of palmettes and lotus palmettes.*

	Inv. Number	Field
	49Tp	D0
	78Tp	D3

Two variations of fields are combined with this border and it is notable that they are the same ones as associated with major border f, described above: namely D0 and D3. This indicates that borders *e* and *f* were probably being used simultaneously for some period. This raises a number of questions: Does border e reflect the rise of a new

workshop or industry competing with *f*? Or does it simply reflect a response to a particular change in fashion?

Major border *d* – *In-and-out lotus palmettes* shares the composition of the previous two borders, but comprises exclusively lotus palmettes (Table VI. 6). In addition, the innovative pin-wheel rosette which appears in major border *e* is maintained here, between the lotus palmettes. This border is associated with two objects: one carpet with Field C2 -*Vine scroll with Central Void and Clouds – Chenar leaf and the other with* Field E - *Tile pattern*.

Table VI. 6: Border group *d – In-and-out lotus palmettes*

Inv. Number	Field
51TP	C2
81Tp	E

Both carpets are the only examples of this particular combination of field and major border, and thus indicating that major border *d* was a less popular border design or applied only in specific circumstances, possibly through commission from a specific workshop.

Major border *c* - *Single vine meander with lotus palmettes and large buds* displays a continuous meander of diagonal lotus flowers alternating with buds (table IV. 7) and is associated with one field variation (*C2 -Vine scroll with Central Void and Clouds – Chenar leaf*) and three objects. This makes it one of the most homogeneous groups, in which all of the objects consist of exactly the same combination of field and border types.

Table IV. 7: Border group *c - Single Vine meander with lotus palmettes and large buds*

Inv. Number	Field
11TP	C2
18TP	
28TP	

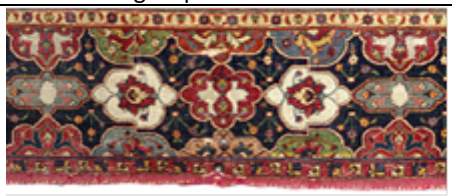
The absence of obvious differences in the level of complexity, density or scale of the motifs in this border type, suggests very little design evolution occurred throughout its production. Such consistency seems to suggest that these objects were made during a narrow period of time and possible also in the same workshop. The presence of field

variation C2 with borders *c* and *d* also suggests that they may be earlier border designs than *e* which is only combined with variations of field D, with the sickle leaf.

Major border a - *Cartouche and Medallion (Vine Scroll carpets)* comprised of sequences of alternating framing devices is seen in two objects, with two field types B and C (Table IV. 8).[33] In terms of their relative chronology, B is considered to be a predecessor of C, and hence border a appears to reflect early production, especially as carpet 26.287 displays the first variation of Field C, namely C0 - *Vine scroll with Central Void and Clouds.*

This notion is also supported by features of carpet T746 (Field B), discussed above in the section IV. 3, namely the presence of a silk foundation and a dense network of two arrangements of scrolling vines with different colors and the so-called 'classical' motifs such as the palmette, horseshoe-shaped and *tchi* clouds, chenar leaf and lotus flower – all of which indicate a close relationship with the earlier 'Tree and Animal' type (Field A).

Table IV. 8: Border group *a - Cartouche and Medallion (Vine Scroll carpets)*

	Inv. Number	Field
	26.287	C0
	T746	B

Major border *g – Lotus palmettes alternating with pairs of curved sickle leaves clasping a rosette* is recognized by the distinctive combination of elements described in its name, especially the pairs of clasping sickle leaves, seen in three objects (table IV. 9). This border is combined with two field designs, namely *D0* and *D1*. These fields share the inclusion of sickle leaves, while the second is distinguished from the first by the absence of horseshoe-shaped clouds. This difference seems to indicate that the exclusion of horseshoe-shaped clouds can represent: 1) a transitory moment in carpet design or 2) an artistic choice of a particular workshop.

[33] Klose, 2003, pp. 73-89.

Table IV. 9: Border group *g – Lotus palmettes alternating with pairs of curved sickle leaves clasping a rosette*

	Inv. Number	Field
	82Tp	D0
	T758	"
	T761	D1

The major borders *b, h* and *f leaves* (table) are also seen in combination with Field D1 – *Vine scroll with Central Void - Sickle leaves, without clouds* (see tables IV. 10, IV. 11 and IV. 4)

Table IV. 10: Border group *b - Arabesque split-leaf vine (alternating with lotus palmettes)*

	Inv. Number	Field
	16TP	D1

Table IV. 11: Border group *h – Pairs of curved sickle leaves clasping lotus palmette*

	Inv. Number	Field
	T757	C3
	66Tp	C4
	21Tp	D1
	T760	"

How can the use of this field with so many different border designs be explained? One possibility is that it represents the mark of a single workshop with considerable design creativity, or alternatively that Field D1 was picked up by several workshops at the same time.

Major border *i – Pairs of curved sickle leaves clasping lotus palmette and palmette or chenar leave* (Table IV. 12) is related to *h – Pairs of curved sickle leaves clasping lotus palmette* (Table IV. 11), and instead of displaying lotus palmettes clasped by sickle leaves, chenar leaves are also included, alternating with lotus flowers. It appears in two carpets in combination with the early variations of the same Field D.

Table IV. 12: Border group *i – Pairs of curved sickle leaves clasping lotus palmette and palmette or chenar leave.*

Inv. Number	Field
T759	D1
26.277	D2

Combined with this new border displaying sickle leaves sinuously drawn, creating a dynamic rhythm within the motifs displayed, while the pomegranate palmette is introduced for the first time. The uniqueness can also be seen in carpet 26.277 (see Appendix D). In addition of being the only object displaying with Field D2 – *Large-scale Vine scroll with Central Void and Clouds – Sickle leaf*, it displays border *i*. Thus it is likely that carpets displaying border *i* represent particular objects, likely commissioned.

Major border *j - Single Vine meander with rosettes and buds* appears in just one carpet with Field C4 - *Vine scroll with Central Void and Clouds – Pin-wheel* (table VI. 13)**.** The presence of this very unique border together with the last version of Field C offers strong support for the idea that border group j represents a production with very precise features. In particular, as no other carpet among the 59 included here shares the same flaming lozenge-shaped medallion in the central field. Therefore, technical and material analysis of this unique carpet will be essential to better increase the understanding of this group.

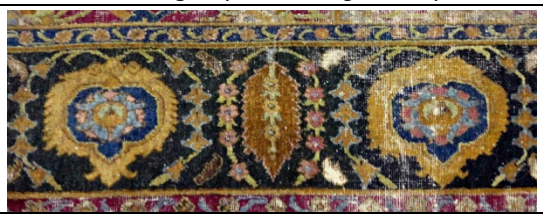
Table IV. 13: Border group *j - Single Vine meander with rosettes and buds*

Inv. Number	Field
T756	C4

All three carpets with major border *k – Pomegranate palmettes alternating with cypress trees* exhibit the same field, namely *F - Tile pattern design – Quatrefoil arabesque split-leaf* (table IV. 14). Such homogeneity suggests a well-circumscribed production in both time and space. The large dimensions objects with border *k* appear to reflect a popular design combination. Motifs of arabesque split-leaf or octafoils, sickle leaves, chenar leaves, lotus palmette and pomegranates are displayed repeatedly in off-set rows.

Such an original composition might reflect a later production, but this idea needs to be further developed together with relative dates for this particular border.

Table IV. 14: Border group *k* – *Pomegranate palmettes alternating with cypress trees*

	Inv. Number	Field
	48TP	F
	67TP	
	75TP	

Finally, major border *l* – *In-and-out palmettes alternating with large meander* appears in two objects with large dimensions (more than 4 meters) (table IV. 15). Their field designs, however, are completely distinctive. The first carpet exhibits Field A – Tree and Animal, while the second one displays Field G – Large-scale geometrical networks of Vine scroll and Sickle leaf (see appendix D for further details).

Table IV. 15: Border group *l* – *In-and-out palmettes alternating with large meander*

	Inv. Number	Field
	1942.9.477	A

To conclude, the twelve major border groups discussed reflect different combinations of the eight main fields (and their variations) with the borders surveyed (see figure IV. 51). The analysis of this correlation reveals that two borders are associated with a single field type, namely major border *c* with field C2, and major border *k* with F. This association suggests that these two border groups reflect production that was well circumscribed in either time and/or space.

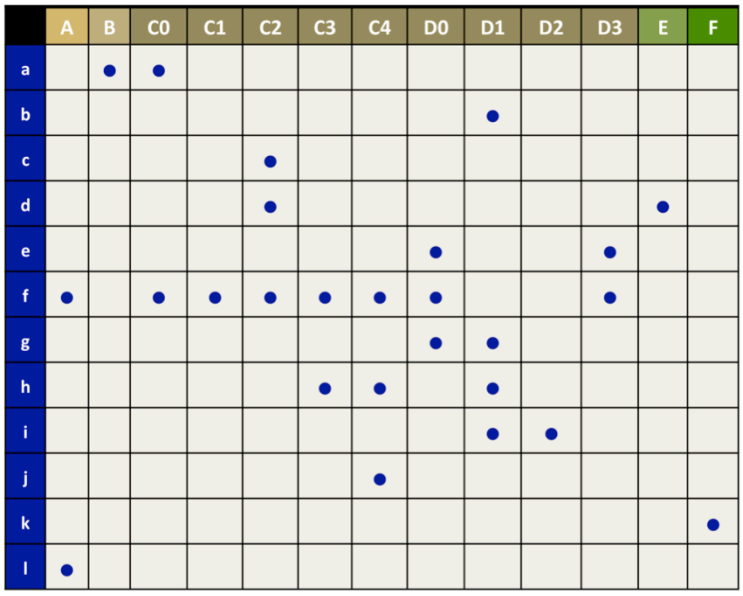


Figure IV. 51: The twelve major border groups resulting from different combinations of fields (letter in the brown to green row) and borders (letters in blue column) surveyed.

Given the proposed relative chronology of the fields, in which C is estimated to precede F, it would appear that major border *c* is probably earlier than *k*. In addition, border *a* appears in association with fields B and C0, the first variation of field C, which could indicate that it is earlier than *c*. Two of the border groups are comprised by a single carpet, namely border *b* with field D1 and border *j* with C4. Although the relative chronology of these two groups (*b* and *j*) remains to be clarified they seem to represent distinctive products.

The most popular border *f* appears with multiple field variations, namely A, all variations of C, as well as D0 and D3. This suggests that border *f* was used over a longer time period than others discussed here. Moreover, border *f* is not associated with Fields B, D1, D2, E, F and G, which could indicate a chronological or geographical difference in the production of carpets displaying such fields.

The remaining five groups comprise a smaller number of field variations, namely major border h with C3, C4 and D1, major border *d* with C2 and E, major border g with D0 and D1, major border *e* with D0 and D3 and ultimately major border *i* with D1 and D2. Moreover, one field (D1) is associated with four different major borders (*b, g, h* and *i*) and two fields (C3 and C4) are associated with two borders (*f* and *h*). This relationship appears to indicate that all of these border groups (*e, f* and *g*) overlapped for a period of time and

possibly reflect regional production involving either a single major industry or several workshops working closely.

Finally, the systematic analysis of their design presented in this chapter offers new clear and suitable labels to the various designs previously described under the 'Indo-Persian' designation. In addition, two significant observations emerge from the design analysis: firstly, some borders appear with a very limited range of field designs suggesting that these carpets were made in localized setting – a workshop or town; secondly, other borders appear to have been more popular and were combined with multiple field designs. This fact can be interpreted in two ways: 1) by transmission of designs between multiple workshops working closely in a wider region or large city, or 2) by an increasing creativity through design experimentation to meet market demand. This relative chronology of design if further refined by looking at their depictions in European paintings, a theme to be addressed and consolidated in Chapter VI. In the next chapter we will look at the carpets through a new perspective, their colors and dyes (Chapter V).

LIST OF APPENDICES

CHAPTER V

COLORS AND DYES

Textiles have been colored throughout history using dyes from across the globe. Sources for dyes are locally available in plants, insects, shellfish and lichens.[1] Due to their extensive use, the analysis of dyes can be an extremely important tool for answering questions of the origin and date of textiles. This is especially true with the rise of synthetic dyes in the mid-18th century, as their use offers a *post-ante quem* date for production.[2]

In earlier centuries natural dyes were used, and specialized knowledge of the craft of dyeing was held by only a few master-dyers. In the past few decades' considerable efforts have been made to increase understanding of the use of natural dye sources, while relating dyeing practices with different textile traditions.[3] Studying natural dyes, however, is a far more complicated matter, as observed by Cardon: "these dyes are made up of groups of molecules that are often numerous, many of which still remain unidentified".[4]

When studying natural dyes used in 16th- and 17th-century textile traditions in Iran and India, one needs to look to the wider geographic context of the West and South Asia. Many researchers have published extensively on dye-sources employed by different civilizations around the world.[5] For countries ranging from Turkey to Pakistan, the works of Cardon[6] and Böhmer[7] are particularly important references

[1] Cardon, 2007.
[2] After the accidental syntesis of mauveine by Perkin in 1856 and its commercialization, coal-tar dyes began to compete with natural dyes. Further information on this matter in Garfield, 2001.
[3] Siva, 2007; Karapanagiotis, et al. 2009; Serrano, et al. 2011; Mouri, Laursen, 2012; Manhita, et al. 2014; Liu, et al., 2013; Serrano, et al., 2013, Santos, et al., 2015; Shibayama, et al., 2015; Gürses, et al., 2016 to name a few.
[4] Cardon, 2007, p. 1.
[5] Brunello, 1973; Cardon, 2007; Böhmer, 2002; Donkin, 2007; Pastoureau, M. 2001; Legrand, 2012.
[6] Cardon, 2007; Böhmer, 2002.
[7] Böhmer, 2002.

that include detailed descriptions of historical recipes, images of dyeing sources and dyeing-processes by traditional dyers, together with some current uses of dyes.

In order to identify workshops equipped for carpet production such as the 'Indo-Persian' carpets in this study, more knowledge of how court and urban workshops operated is required. Likewise, it is necessary to comprehend the physical space and division of labor in the workshop, to understand who was responsible for the aesthetics, the design, the composition and the colors, and who was in charge of choosing and acquiring the raw materials.[8] Through scholarly works and numerous papers one learns about the large variety of dye-sources and their preferred use in the West and South Asia.[9] Availability and light fastness also played a significant role in the process of selecting specific dye-sources.

V. 1. Colors

Animal and vegetal dye-sources can provide a wide range of colors. Moreover, it is known that many natural dye sources were obtained from different parts of plants such as the seeds, roots, stems, leaves, flowers, fruits, etc. Thus, the use and preference for a certain dyestuff would be dependent on the availability of the plants, skills and knowledge of master-dyers to achieve desired hues in a workshop. The validation of the significance of the materials collected from historical records relies on analysis of historical objects. Thus, modern science has been essential in

[8] Porter, 1994. During 14th and 15th centuries in Europe "(…) certain German and Italian cities, specialization among dyers was taken even further: among those producing the same color, dyers were distinguished by which coloring substance they had the right to use. For example, in Nuremburg and Milan in the fourteenth and fifteenth century, red dyers who employed madder, which grew abundantly in Western Europe and was reasonably priced, had a legal status different from that of dyers who used cochineal dye and kermes, products that were imported at great expense from Eastern Europe and the Middle East. Each group paid different taxes and obeyed different regulations, each used different techniques and mordants, and each had a different clientele." in *Blue: The History of a Color*, by Michel Pastoureau, p. 70.

[9] Shibayama, et al., 2015; Santos, 2010, pp. 10-22; Shibayama, 2010 a); Shibayama, 2010 b); Cohen, Kajitani, 2006; Heitor, Sousa, Melo, 2007, pp. 161-168; Arminho, Sousa, Melo, Hallett, 2008, pp. 960-966.

uncovering new information by studying historical Iranian and Indian textiles with from significant collections.[10]

The variety of possible dyes for red, yellow and brown colors available to Iranian and Indian dyers is outlined below, and followed by a full discussion of the dye analyses and results. First, by describing the results obtained for the analysis of each individual color, then begins to establish groups of objects based on the compounds from their red and yellow colors.

V. 2. Dyes

Red dye sources

Several dye-sources are recognized to occur in Iran and surrounding regions in West Asia, while others are closely associated with India and Southeast Asia. Scale insect sources are responsible for the majority of red colors in historical textiles.[11] Dyer's Kermes (*Kermes vermilio* Planchon), Cochineal (*Dactylopius* sp. and *Porphyrophora* sp.) and Lac dye (*Laccifer Lacca Kerr*) are parasitic insects hosted by different plants occurring in different regions, known to be used by different textile traditions.[12]

Cochineal and lac dye insects comprise different compounds and minor compounds making them easily distinct.[13] The usage of cochineal in textiles is frequently detected due to the presence of its main chromophore, carminic acid (2-C-glucopyranoside of kermesic acid) and other minor such as dcII (2-C-glucopyranoside of flavokermesic acid), dcIV (2-C-α-glucopyranoside of kermesic acid), dcVII (2-C-β-glucopyranoside of kermesic acid), flavokermesic acid and kermesic acid.[14] Polish and Armenian cochineal species (*Porphyrophora polonica* Linnaeus and *Porphyrophora hamelii* Brandt) are stated to have been one of the

[10] Idem.
[11] Wouters, 1985; Wouters and Verhecken, 1989a; Wouters and Verhecken, 1989b; Santos, 2010; Serrano et al. 2011; Santos et al. 2015; Phipps, E. 2010b.
[12] Brunello, 1973; Donkin, 1977; Böhmer, 2002; Hofenk de Graaff, 2004; Cardon, 2007; Phipps, E. 2010a; Phipps, E. 2010b.
[13] Stathopoulou, et al., 2013; Santos, et al, 2015.
[14] Wouters and Verhecken, 1989a.

major sources prior 16th century in Eurasia.[15] Sometime after 1521, with the first cargos arrived from Mexico, American cochineal (*Dactylopius coccus* Costa) start to be used in Europe, rapidly replacing other insect reds for its richer colorant content and, thus, cheaper price.[16]

In the recent years, textile and taxonomic studies have been exploring new methodologies, using advance analytical techniques, to enhance our knowledge for an identification and distinction of other insect reds, such as *Kerria* spp. (lac dye).[17] Lac dye is a natural red dye used in works of art obtained from lac-insects from the Kerriidae family. The *Kerria* genera comprises 26 species - primarily found in India, China, Taiwan, Sri Lanka, Australia and Pakistan - amongst which *Kerria lacca* Kerr is most frequently reported for its use in historical textiles. Lac comes into the market in many forms – sticklac, shellac, seed lac, etc – that comprise different matters. The red coloring matter is soluble in water and contains the laccaic acids A, B, C, D (or flavokermesic acid) and E, principal chromophores of lac dye.[18]

Kermesic acid and flavokermesic, are major and minor chromophores, respectively, of the insect *Kermes vermilio* Planchon from the Kermesidae family. *Kermes vermilio* Planchon is native to Mediterranean regions, where kermes oak (*Quercus coccifera* L.) its host plant grows.[19] Kermes was not an exclusive item in trade monopoly for Mediterranean communities, as it appears to have been one of the precious but easily transportable products traded along the Silk Road.[20] Kermes

[15] "The Persian kings, especially those of the Achaemenid dynasty, were other important customers. Being lovers of Luxury and splendor, the cloth purple exercised an irresistible fascination for them. When Darius went to meet Alexander the Great, he wore one of these garments embroidered in white. In 331 B.C., Alexander conquered the Persian capital, Susa, and, in the royal treasury, he discovered some purple garments that were worth five thousand talents. It was averred that even though these garments were about two hundred years old, they still retained a remarkable freshness. (…) The heirs of this refined art are the creators of the famous Persian carpets that are greatly admired for their original designs vivified by refined polychrome coloring. The colors in these carpets, applied with a dyeing technique that is the result of many centuries of experience, are perhaps the same as those of the time of Darius (…)" in Brunello, 1973; Donkin, 1977.

[16] Donkin, 1977; Hofenk de Graaff, 2004; Serrano et al. 2011; Serrano, 2016.

[17] Serrano et al. 2011; Serrano et al. 2013; Santos et al. 2015.

[18] Santos et al. 2015; Cardon, 2007.

[19] Cardon, 2007, p. 610; Böhmer, 2002

[20] Cardon, 2007, p. 617.

insect were expensive red insect dye use in historical textiles. It is reported to be distinguishable alone but not in mixtures with cochineal or lac, since they share similar compounds.[21]

On the other hand, several studies report the use of vegetal dye-sources to attain red colored fibers in historical textiles.[22] *Rubia* sp. (madder) or *Oldenlandia umbellata* L. (Chay or Chayroot) are among the most prevalent, with Madder being often associated with European and Turkish dyeing practices.[23] Though, Porter explains that *Rubia tinctorum* L. was abundant in Iran, cultivated in Fars and Isfahan, and imported to India by Iranian dyers working there.[24] Nonetheless, as occurs with most plants species of Rubiaceae they can be found in several locations worldwide. While *Rubia tinctorum* L. is vastly known and used in the West, *Rubia akane* Nakai is used as a dyestuff in Japan for centuries.[25] Thus making species identification extremely significant for purpose of providing information about its history and technology of dyeing practices applied in historical textiles produced elsewhere.

Recent dye studies clarify that textiles dyed with *Rubia tinctorum* L. contain primarily alizarin, while other dyed with *Rubia cordifolia* L. *and Rubia peregrina* L. contain mostly purpurin, munjistin and pseudopurpurin with small or no traces of alizarin. Yet, no reliable distinction between the latter two is possible.[26] Also, Lady's Bedstraw (*Galium verum* L.) found in Western Asia to Himalayas is known by

[21] Serrano, et al. 2015: "(…) it has been demonstrated that compounds ratio in the colorant composition are directly related to the type of fibres (especially silk) used and the dyeing parameters applied to them, because of different types of reactions occurring between the fibres and insects' colorants".

[22] Whiting, 1981; Ingamells, 1993; Enez and Böhmer, 1996; Pastoureau, 2001; Santos, 2010; 11; Leck, K. and Jarosz M., 2011; Mantzouris, et al., 2011; Siva, 2007.

[23] "Beginning in the 1230's woad, like madder, was produced on practically an industrial scale in order to satisfy the growing demands of weavers and dyers. (…) Numerous documents attest to violent conflicts between merchants of madder (used to make red dye) and woad, reflecting the economic stakes of changing fashions in color (…)" in Pastoureau, 2001, pp.63-66; Böhmer, 2002; Cardon, 2007; Garfield, 2001, p. 90.

[24] "Let us say a word about madder (*Rubia tinctoria, runas*) because, even though it is mentioned only occasionally here, it is undoubtedly the most abundantly used red dye in Iran. Extensively grown in Iran, In Fars and Isfahan, madder was imported into India by Iranian dyers who were working in that country" in Porter, 2007, p. 40.

[25] Mouri, Laursen, 2012.

[26] Wouters J. 1985; Mouri, Laursen, 2012.

providing an orange-red color, characterized by pseudopurpurin, munjistin, rubiadin.[27]

Sappanwood (*Caesalpinia sappan* L.) belongs to the group of Redwoods[28], particularly to a type of trees with soluble redwoods. Redwoods first came from Java around 1350, but its use as a mordent dye is reported from late 12th century.[29] Sappanwood grows mainly in hilly areas at low or medium altitudes with clay soil and calcareous rocks and is known to be native to the region between central and Southern India through Burma, Thailand, Indochina and Southern China to peninsular Malaysia.

In his work Porter states: "This wood is produced in the Caspian forests and in the Deccan. When it is fresh, it has a pale color which reddens when exposed to air".[30] However, large quantities of sappanwood imported to Europe from India and Southeast Asia are stated in Portuguese documentation.[31] Depending on the acidity of the dye bath the colors obtained for silk, wool and cotton fibers can range from orange to red color hues. The red color is not lightfast, thus the presence of sappanwood in historical textiles is often recognized by the presence of the colorless soluble redwood component, its characteristic compound.[32]

Yellow dye sources

The importance of local availability is particularly significant for yellow dye-sources. Their easy accessibility and vast variety are believed to have led to local sourcing. However, one cannot exclude the possibility that some well-equipped and endowed workshops were using trade to obtain high quality yellow-dyestuff from far-off regions.

[27] Böhmer, 2002, p. 123.
[28] "Redwoods are tropical woods whose heartwood contains red dyestuffs, both soluble and insoluble in water, thus the differentiation between "soluble" and "insoluble" redwoods". In Böhmer, 2002, p. 180; for further details on this matter, particularly, on the definitions of "soluble" and "insoluble" redwoods see Surowiec, et al. 2004.
[29] Böhmer, 2002, p. 181.
[30] Porter, 1994, p. 40.
[31] Cardon, 2007, p. 275.
[32] Karapagionis, et al., 2009; Surowiec, et al. 2004; Manhita, et al. 2011.

Numerous yellow dye-sources of variable quality are found to be native to various geographical locations ranging from Europe to China. However, knowledge of their use in dyeing practices from local textile tradition is reported for some more than others. Significant yellow dye-sources used in Iran and India, as well as surrounding areas, will be characterized in the subsequent paragraphs. Later, establishing difference between dye-sources occurring in Iran, India and surrounding areas, and dye-sources found in historical textiles or mentioned in historical recipes from textile Iranian or Indian traditions.

Some of the plants known to have been use for their coloring properties are *Rhamnus saxatilis* Jacq. (Persian Berries), *Serratula tinctoria* L. (Saw-wort), *Phlomis armeniaca* Willd, *Daphne oleoides* Schreber and *Daphne gnidium* L. (Flax-leave Daphne). With the exception of Persian Berries, these are luteolin based yellow dye-sources native to Turkey and/or surrounding regions. Persian Berries from the Rhamnaceae family are recognized to grow on calcareous soils in the Mediterranean region. Saw-wort is commonly found in meadows, woods and hills of temperate areas of Europe and Asia. *Serratula coronata* L., one particular species of saw-wort, is found to develop in mountain fields in Eastern Europe, central and East Asia or Siberia.[33] Saw-wort delivers colors ranging from yellow to orange with acceptable light fastness, with apigenin and kaempferol as its major compounds.[34]

The dyestuffs most associated with yellow-dye practices in classical times in Europe, the Mediterranean and the Middle East are *Reseda luteola* L. (Weld), *Cotinus coggygria* Scop. (Young fustic) and *Delphinium semibarbatum* L. (Yellow Larkspur). The first, weld, is a luteolin-based dye that was most appreciated for its beautiful color and light fastness.[35] Commonly found in Ottoman and Iranian historical textiles from the classical period, yet it was also identified in Portuguese textiles from 17th to 19th centuries.[36] Young fustic is a fisetin-based dye attributed

[33] Cardon, 2007.
[34] Böhmer, 2002, p.196.
[35] Cardon, 2007, p.168.
[36] Shibayama, et al., 2015; Cardon, 2007, p. 176; Böhmer, 2002, p. 36, n.32; Enez and Böhmer, 1996; Marques, et al., 2009; Manhita, et al. 2014.

to Southern and Central Europe, extended to Slovakia, Ukraine and Turkey. In fact, it was a highly appreciated yellow dyestuff in Mediterranean Europe, especially in Italy, for the dyeing of silk and wool.[37]

Yellow Larkspur can be found in central Asia, Iran, Afghanistan, Northern Pakistan and India.[38] Its use is also reported in recipes from Ahmedabad, India and regions of Sialkot and Gujranwala, Pakistan to dye cotton and wool giving it a bright yellow. The dye-matter from yellow larkspur can be obtained from flowers, leaves and stems, and characterized by the occurrence quercetin, kaempferol and isorhamnetin, major chromophores.[39] In historical textiles, the use of Yellow Larkspur has been reported in Islamic carpets and velvets from the Safavid period, which attests to its use in silk dyeing.[40] In addition, some recipes mention the use of boiled *Punica granatum* L. skin extract (pomegranate) skin extract or the root of *Datisca cannabina* L. as mordent in the dye-bath with yellow-larkspur.[41] Both *Punica granatum* L. and *Datisca cannabina* L. are sources of tannins.[42]

The species *Datisca cannabina* L. is known as bastard hemp. It can be found in a wide geographical area that can range from Mediterranean regions (Crete to Turkey), through Central Asia to as Far East as Nepal at the northeast border of what is today India. Bastard hemp has sprays of yellow flowers but its yellow dye is derived from the roots.[43]

Pomegranate (*Punica granatum* L.) is native to southwestern Asia from India and Pakistan to Iran. Used as a dyestuff since Antiquity, it is still today a highly appreciated fruit known to be used as dyestuff by textile industries in Middle-

[37] Cardon, 2007, p.192.
[38] Böhmer, 2002, p.185.
[39] Idem, p.185.
[40] Shibayama et al., 2015; Shibayama, Nobuko. 2010a; Shibayama, Nobuko. 2010b; Santos, et al. 2013.
[41] "Substances including metallic salts such as copper, iron, and aluminium which combine with colorants and fibres by the addition of it in a dyeing process in order to improve the fastness of the dyeing against water, light, and perspiration when the colorants have little affinity with fibres" in Yi E., Cho J. 2008, p. 149.
[42] Cardon, 2007, p. 207.
[43] Encyclopedia Britannica: https://www.britannica.com/plant/Datiscaceae (accessed in 10/08/16)

Eastern countries, for example Afghanistan.[44] Tannins, gallic and ellagic acids and other as yet unidentified yellow compounds are frequently found in pomegranate peels.[45]

Crocus sativus L. (Saffron), *Tectona grandis* L.f. (Teak), *Solidago grandis* DC. (Golden rod), *Tagetes* sp. (Marigold), *Butea Monosperma* L. (Flame of the forest), and *Curcuma longa* L. (Turmeric) are yellow dye-sources associated with dyeing practices in India and Southeast Asia.[46] The presence of turmeric in 19th-century Chinese textiles is well reported[47], yet its use and trade can be traced back to the Roman Empire.[48] It can be found in tropic and subtropics from Africa to India, Sri Lanka, Indonesia, and southern China. Applied to dye cotton, wool and silk fibers, which depending on the type of dyeing (direct or mordant) can vary from yellow to orange-yellow. Turmeric's major chromophore curcumin has been identified in Indian velvets from the 16th to 18th centuries.[49]

Brown dye sources

For a better understanding of the usage of dye-sources in brown colors more research is required. However, evidence of several plants used as dye-sources for brown colors is provided in the bibliography. These can be found in areas from the Mediterranean to Southeast Asia. Among them are *Juglans regia* L. (Walnut tree) with juglone as its main chromophore and excellent light fastness, *Quercus robur* L., *Quercus infectoria* Oliv., *Quercus aegilops* L. *all* rich in tannins or *Rhus coriaria* L. (Sicilian sumac), together with myricetin and quercitrin as the major chromophores in its composition.[50]

[44] Porter, 2007, p. 41; Guliyev V., Gadirova I. 2013.
[45] Böhmer, 2002, p. 156.
[46] Cardon, 2007, p. 319-321; Böhmer, 2002; Siva, 2007; Rasheed et al., 2010; Mayer, 1993.
[47] Zhang, et al., 2007.
[48] Böhmer, 2002, p. 194.
[49] Shibayama, et al., 2015.
[50] Böhmer, 2002; Shahid, et al., 2012**;** http://www.kew.org/science-conservation/plants-fungi/quercus-robur-english-oak (accessed in 10/08/16); (ed) Davis, et al., 1988, p. 470 and 515.

Acacia catechu (L.f.) Willd (Cutch Tree) is native to India, Sri Lanka and Southeast Asia, yet its usage as a brown-dyestuff, in direct or mordant dyeing, has been known in India for thousands of years.[51] Its availability and light fastness, together with adjustability to several dyeing processes turn it into a very desirable dye-source. Tannins are the main dye compounds found in cutch tree. Another dye-source native to India and Ski-Lanka used for brown colors is *Anogeissus latifolia* Wall. (Indian sumac).

It is against this background that Iranian and Indian master dyers prepared the colored yarns used for the carpets studied here. However, identifying the precise source requires access to appropriate samples and sophisticated analytical instrumentation, the performance of analytical techniques and a well-conceived experimental methodology.

V. 2. 1. Samples and methods

A total 762 historical wool textile samples collected from 59 objects; seven carpets recognized as 'Indian', two as 'Early Safavid' objects and the remaining fifty carpets are labeled as 'Indo-Persian' and attributed to Iran (Iran?). Such attribution lacks corroboration, therefore over 800 dye-analyses were conducted using High Performance Liquid Chromatography coupled with Mass Spectrometry (HPLC-MS). This high sensitive analytical technique combines the separation capabilities of liquid chromatography with the molecular identification of mass spectrometry to understand if identical compounds exist between the 'Indo-Persian' and the Early Safavid and Indian objects. Moreover, reference database was developed using several chemical standards, insect species, and wool samples dyed using plants collected in Iran to further improve the identification of dye compounds present in the historical wool samples. On the basis of statistical methods the resulting data was interpreted. Initially, by looking into results from individual colors, then by

[51] Böhmer, 2002, p. 198.

combining results from red and yellow colors – as they are present in the vast majority of the objects. Finally, the subsequent groups of objects are interpreted.

V. 2. 1. 1. Dye analysis

Two or three samples from each color were collected from different areas of the object and, whenever possible, from field and border of each carpet to ensure representative results. This procedure took into consideration, in all cases, the number of hues as well as the state of conservation of the object, thereby avoiding any threat to the physical condition and preservation of the carpets (figures V. 8 and V. 9).

Figure V. 8: Image taken during sampling procedure.

Figure V. 9: Example of a 0,2 mg yellow historical sample collected from carpet 59Tp.

For the first time dye analysis was conducted on red, pink, yellow, orange and brown colors from these objects using High Performance Liquid Chromatography and Mass Spectrometry (HPLC-MS). Together, these analytical techniques enabled the achievement of more accurate results for detail characterization and, thus, the distinction of dye-sources.

Both techniques were conducted at the José de Figueiredo Laboratory (LJF-DGPC) (Lisboa) and at the Department of Conservation and Scientific Research of the Freer and Arthur M. Sackler Galleries of Art, Smithsonian Institution (DCSR-FSGA) (Washington, DC). At the LJF-DGPC José de Figueiredo Laboratory, an LC-MS from Waters® with Millennium 32 software was used, while at DCSR-FSGA, a Shimadzu LC-MS and Labsolution 5.11 software was used. Nevertheless, the procedures used to analyze samples are the same (details are given in Appendix F),

using a mild extraction method – oxalic acid (0.2M): acetone: methanol: water (0.1: 3: 3: 4, v/v/v/v) as extraction solution.[52]

A reference database was built with several chemical standards and other references, including samples from the *Asian Organic Colorants* project from the Getty Conservation Institute[53] as well as two sets of wool samples dyed using plants collected in Iran, one from Dr. Richard Laursen (Department of Chemistry, Boston University, Boston MA, USA) and another from the project *Redevelopment of traditional Plant-based dyeing Techniques in Iran to help women in local communities become Self-supporting* from Toyo Bunko.[54]

Of the 59 carpets and carpet fragments included in our study, seven are recognized to have an Indian origin (Mughal and Deccani) and other 52 are currently classified under the 'Indo-Persian' designation and attributed to Iran on the basis of their technique. In total 762 historical wool textile samples were collected from objects belonging to Museu Nacional de Arte Antiga and Museu Nacional de Machado de Castro (Portugal), The Textile Museum, The National Gallery of Art and the former Corcoran Gallery of Art, all based in Washington, DC. Over 800 analyses were conducted and the results were then analyzed using chromatographic techniques and interpreted on the basis of statistical methods, discussed below. This large amount of chemical data is then further related with and art historical evidence in Chapter IV – Designs, in order to attain more detailed conclusions to establish groups of carpets and associate them with different workshops in Chapter VII – Production and Consumption.

[52] Wouters, et al., 2011, pp. 231-249.
[53] Analyzed at DCSR-FSGA by Dr. Ana Claro HERCULES Laboratory, Universidade de Évora and Center for Overseas History (CHAM), Faculdade de Ciências Sociais e Humanas - Universidade Nova de Lisboa, Portugal.
[54] Dr. Chika Mouri (Freer|Sackler Deparment of Conservation and Scientific Research, Smithsonian Institution) made these reference samples available to this doctoral project.

V. 2. 1. 2. Chemometrics

Processing thousands of spectra collected from the more than 800 dye analyses performed by HPLC-MS represented an enormous challenge for this study. Understanding such a large amount of data (samples, colors and variables), while ensuring minimum information loss required the use of specialized techniques of data analysis. As stated by Reedy[55] statistics are frequently used to describe objects, estimate the characteristics of a population from a sample, and test hypotheses or ideas about the subject of a study.

Several conservation research projects have used statistical analysis and multivariate analysis tools to optimize the use of the data collected. However, when approaching art materials, and especially art objects, two particular characteristics need to be considered regarding the variability in any statistical analysis: 1) the object individuality, i.e., distinct composition, form or history and 2) heterogeneity between objects, i.e., which features should and can be related or, in the case of palette studies, what colors and compounds one should look at. Such variability requires attentive consideration of the statistical procedures used at each stage of data analysis. Preferably, the selection of the most appropriate method of statistical analysis for a given project is a result of careful reflection on both the scientific questions to be answered and the structure of the data collected.[56]

When considering the data one must focus on three major areas: the objects' authentication, provenance and color palette. The aim of this study is to organize the available carpets by similarity, taking into consideration for that purpose all available information, from such diverse origins as design analysis to fibers, techniques and chemical composition of the dyes. Due to the complexity and amount of information obtained from the chemical analysis (HPLC-MS) of dyes present in carpet samples, multivariate analysis is of great importance for extracting the relevant information for dye and object classification. Thus, Principal

[55] Reedy, 1988, p. 3.
[56] Reedy, 1988, p. 3.

Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) have been used for this purpose.

Chemometrics techniques are based on data and often used in domains such as chemistry or engineering for purposes of measurements with the goal "to efficiently produce an empirical or semi-empirical model, derived from data, which is used to estimate one or more properties of a system from measurements".[57] The effectiveness of such techniques in textile studies was proven in previous studies on *Laccifer Lacca Kerr* and *Paratachardina* sp. (lac dye) and *Dactylopius coccus* sp. (cochineal).[58]

This study had the collaboration of Dr. Jorge Sarraguça from LAQV / REQUIMTE at Faculdade de Farmácia, Universidade do Porto (Porto, Portugal), who performed the statistical analysis.[59] Principal component Analysis (PCA) was used as a data compression and information extraction tool for exploratory analysis of the dyes according to chemical composition retrieved from the HPLC-MS analysis. Working with datasets where each sample is described by a large number of variables often implies that a great deal of correlated or redundant information is present, and thus information must be compressed in a manner that retains the essential information and is more easily displayed than each of the variables individually (for more information see Appendix F).

[57] Wise, Gallagher, and Windig, 2006, p. 95.
[58] Santos, et al., 2015; Serrano, et al., 2011; Serrano, et al, 2003.
[59] Results of dye analysis by HPLC-MS were compiled in a data table according to chemical composition and provided to Sarraguça (LAQV / REQUIMTE, Laboratório de Química Aplicada, Departamento de Química, Faculdade de Farmácia da Universidade do Porto, Rua Jorge Viterbo, n.º 228, 4050-313 PORTO) who built the static model. The model was optimized collaboratively and Sarraguça produced report for each color, followed by final report combining all colors.

V. 2. 2. Results

V. 2. 2. 1. Reference samples

A reference database was developed using several chemical standards, insect species, and wool samples dyed using plants collected in Iran, such as *Euphorbia* sp. (*Euphorbia rigida* M. Bieb [60]), *Nonea* sp., *Papaver* sp., *Prangos* sp., Anacardiaceae - which include possibilities such as turpentine tree, wild pistachio, dyer's sumac, sicilian sumac, Lamiaceae.[61] Furthermore, fiber samples belonging to the *Asian Organic Colorants* project from the Getty Conservation Institute (Los Angeles, CA) and to the project *Redevelopment of traditional Plant-based dyeing Techniques in Iran to help women in local communities become Self-supporting* from Toyo Bunko (Japan).

The list of all compounds found on the reference samples is given in Appendix G. The reference samples analysis permitted the identification of some unknown compounds detected in historical samples. Some of these compounds were identified in several reference samples, thus restraining their association with a family or more specific dye-source. From a total of 16 wool samples dyed using plants collected in Iran, something often incredible difficult to obtain, approximately fourteen had non-unique compounds. Nevertheless, all reference samples presented an unique combination of these compounds, providing chemical markers for each dye source (Appendix G). These were later used to identify the compounds found in the historical samples as discussed in the next section.

V.2.2.2 – Historical samples – All individual colors

Historical samples from red, pink, yellow, orange and brown colors from the 59 objects, including fragments, were analyzed. The results from the chemical data of each individual color are presented below and all compounds found are described

[60] Böhmer, 2002, p. 162.
[61] Böhmer, 2002, pp. 154, 155 and 165.

and listed in Appendix H. The approach taken here starts by looking to red colored historical samples and then follows to pink, yellow, orange and brown ones. In each of these colors compounds were detected using High Performance Liquid Chromatography and Mass Spectrometry (HPLC-MS).

The results from this data were process afterwards using statistical methods, comprised first by a PCA – data compression from dyes according to chemical composition retrieved from HPLC into clusters – groups of compounds and objects, followed by Hierarchical Cluster Analysis (HCA), a tree shaped graphical representation reflecting the association between samples, on the basis of the detected compounds. A summary of these results is presented in a table accompanied by a discussion of their significance. Moreover, when referring to results of any color included in this study, one should note that differentiation between its clusters relies on the use of both a color and a symbol – *i.e.* Red cluster (circles). Therefore, the use of the term Red cluster (circle) can be found to describe a particular cluster in red, pink, yellow, orange or brown samples. Finally, the groups obtained from the results of red and yellow historical samples are then used to refine groups of carpets and the interpretation of their origin.

Reds

Results from the analysis of the red historical samples from 54 carpets (all objects from the available set in which the color red was used) revealed that lac dye from *Laccifer Lacca Kerr* was used to obtain the red colors in carpets attributed to Iran or India (Mughal and Deccan). Together with *Kerria* species, sappanwood was also found to be one of the principal dye-sources. Identification of lac dye in an Iranian carpet (figure V. 10) and sappanwood in an Indian carpet (figure V. 11) was accomplished through their UV-Vis and MS spectra as seen in the figures. However, in combination with expected compounds from the two major dye sources, *Kerria* and sappanwood, additional compounds were detected (see table V. 1).

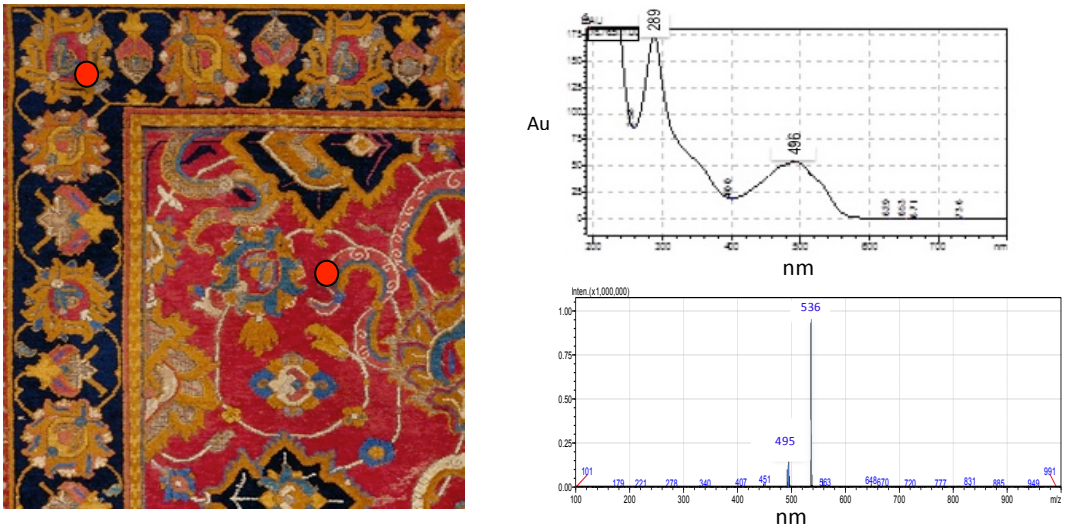


Figure V. 10: Detail of red sampled areas from an Iranian carpet (Inv. No. 28Tp) belonging to MNAA. Correspondent Laccaic Acid A compound UV-VIS and MS spectra, attesting the presence of Lac dye.

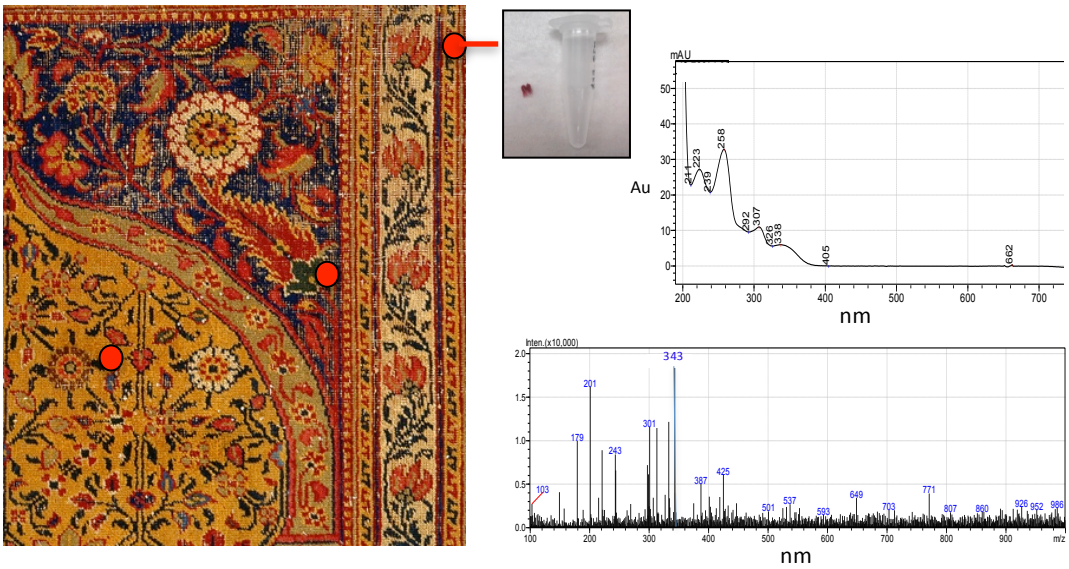


Figure V. 11: Sampled areas for reds from an Indian carpet (Inv. No. 12Tp) belonging to MNAA. Image of a red sample (0.13 mg), with its 4 cm long container. At bottom right are UV-VIS and MS spectra acquired, corresponding to soluble redwood component attesting the presence of sappanwood.

Figure V. 12 shows a graphical representation of loadings obtained for the PCA analysis of red historical samples. The loadings plots display the descriptive chemical compounds determined by the HPLC-MS analysis (figures V. 12, V. 13 and V. 16b).

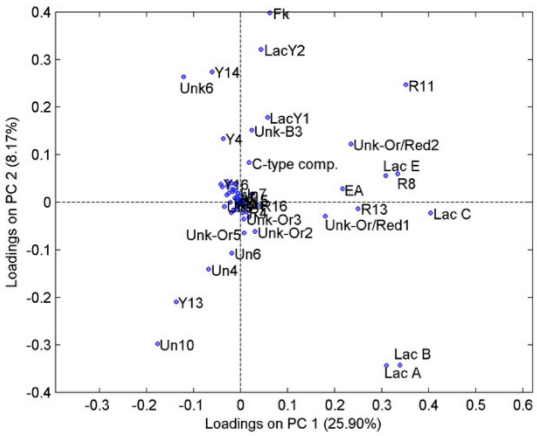


Figure V. 12: PC1 vs PC2 loadings for principal component analysis of all samples of red pigments. Graph courtesy: Jorge Sarraguça.

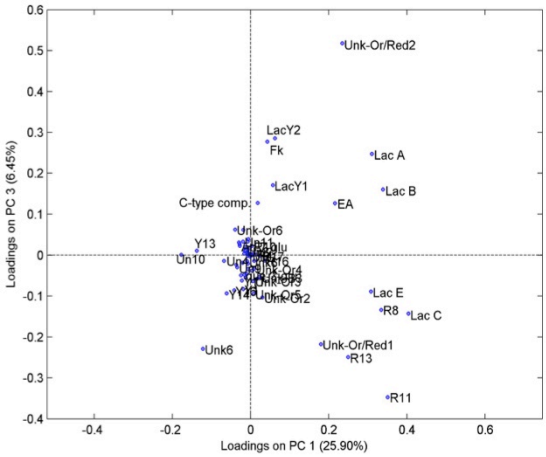
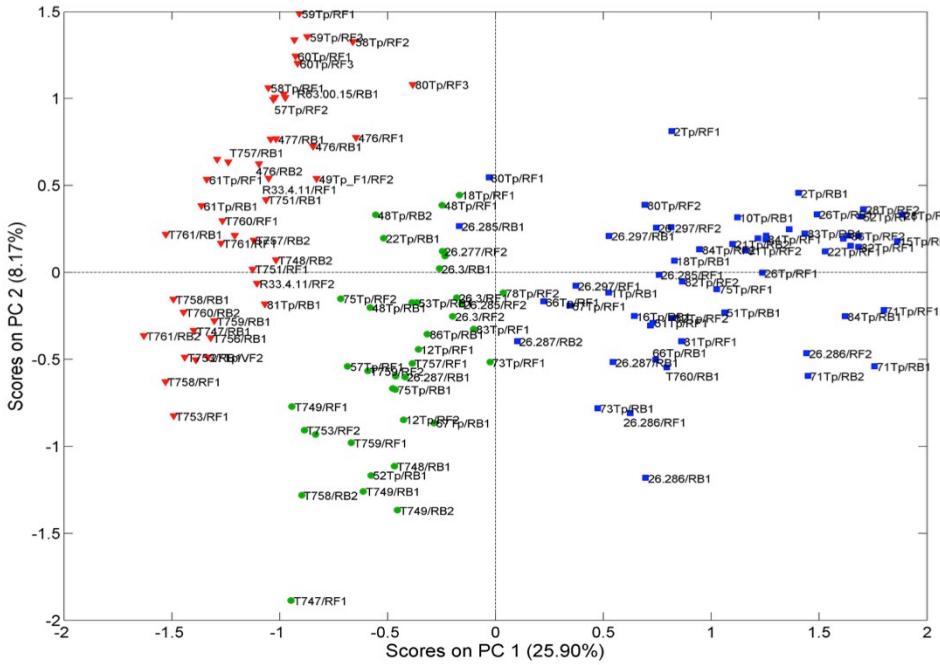


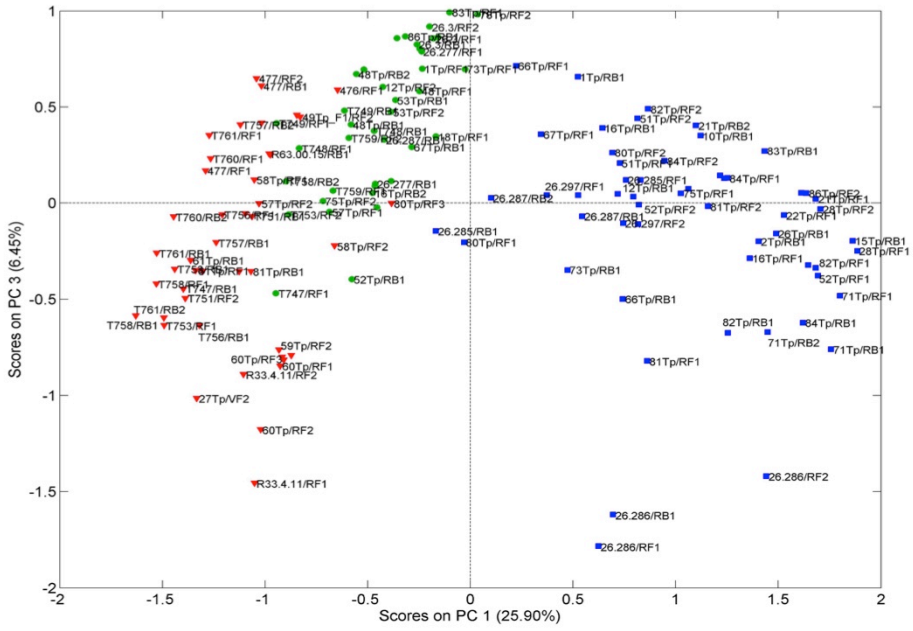
Figure V. 13: PC1 vs PC3 loadings for principal component analysis of all samples of red pigments. Graph courtesy: Jorge Sarraguça.

These are responsible for the main variance in the samples and can essentially be grouped into six groups of a correlation pattern: i) laccaic acids A and B; ii) laccaic acids C and E, unknown red compounds 8 and 13 and orang/red compound 1; iii) lac yellows 1 and 2, flavokermesic acid and soluble redwood component; iv) unknown yellow compound 14 and colorless compound 6; v) unknown yellow compound 4 and UnkB3; vi) unknown yellow compound 13, colorless compounds 4 and 10. Some more chemical compounds are observed to be responsible for a significant degree of variance within the samples, although not being correlated to others, as is the case for colorless compounds 4 and 8, unknown orang/red compound 2, ellagic acid and unknown red compounds 10.

Figures V. 14a and V. 14b show the PCA model scores for PC1 vs. PC2 and PC1 vs PC3 for the same analysis. The scores appear to cluster in three large groups essentially separated along PC1. A characterization of the samples based on the chemical composition can be extracted from the PCA by analysing the scores values, in conjunction with hierarchical cluster analysis. As a result, three groups (corresponding to different colors in the score plots) were obtained by Hierarchical Cluster Analysis (HCA), using Ward's method clustering with approximately 40% cumulative variance captured.



a)



b)

Figure III. 14: PC1 vs PC2 (a) and PC1 vs PC3 (b) scores obtained for the PCA of all red colored samples. Scores colored according to groups resulting from HCA. Graph courtesy: Jorge Sarraguça.

The dendrogram depicting group formation is presented in figure V. 15. The three groups resulted from a variance-weighted distance between cluster centers exceeding 15.

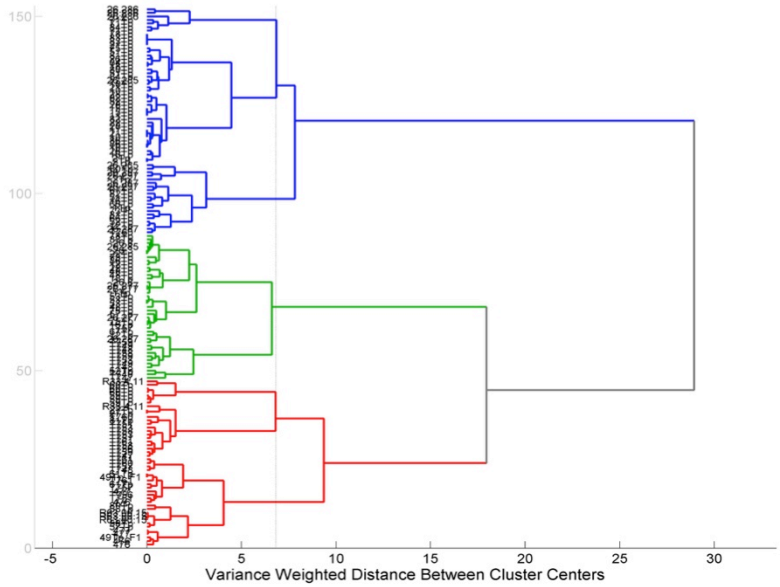


Figure V. 15: Dendrogram resulting from hierarchical cluster analysis of the scores of the first 3 principal components in PCA using all red colored samples chemical composition as input data. Graph courtesy: Jorge Sarraguça.

The classification into three large groups may provide some leads for a future research on geographical origin based on chemical composition of colorants. Table V. 1 summarizes information for each cluster, the existing compounds with a significant influence to the cluster assembly and accession numbers of the objects included in the cluster, along with their correspondent fields and border designs. In addition, it provides information about which carpets are shared by more than one cluster, together with their correspondent field and border designs.

Table V. 1: Distribution of carpets obtained from HCA based on PCA scores results for all red-colored historical samples (nPC=3 dist=15).

Cluster	Defining compounds	Carpets	Design	Carpets in multiple clusters	Design
Red (Triangles)	Fk; Lac Y1; Lac Y2; C-type comp.; Unk-B3; Unk-Or3 and Unk-Or5; Y4; Y13; Un4; Un6; Un8; Un10; Y14	27Tp; 476; 477; 49Tp_F1; 57Tp; 58Tp; 59Tp; 60Tp; 61Tp; 80Tp; 81Tp; R33.4.11; R63.00.15; T747; T748; T751; T753; T756; T757; T758; T759; T760; T761	**Field:** A, C0, C2, C3, C4, D0, D1, D2, E, G, India **Border:** d, e, f, g, i, j, l	57Tp; 80Tp; 81Tp; T747; T748; T753; T757; T758; T759; T760	**Field:** C0, C2, C3, D0, D1, D2, E, G **Border:** d, f, g, i
Green (Circles)	C-type comp.; Unk-B3; Lac Y1; Lac Y2; Unk-Or4; Unk-Or5; que-3-glu; R16; R17; Y13; Y14; Un4; Un6; Un8; Un10; Un11	1Tp; 12Tp; 16Tp; 18Tp; 22Tp; 26.277; 26.285; 26.287; 26.300; 48Tp; 52Tp; 53Tp; 57Tp; 67Tp; 73Tp; 75Tp; 78Tp; 83Tp; 86Tp; T747; T748; T749; T753; T757; T758; T759	**Field:** C0, C2, C3, C4 D0, D1, D2, D3, F, G, India **Border:** a, b, c, e, f, g, l, k	1Tp; 12Tp; 16Tp; 18Tp; 22Tp; 52Tp; 67Tp; 73Tp; 75Tp; 78Tp; 83Tp; 86Tp; T747; T748; T753; T757; T758; T759; 26.285, 26.287	**Field:** C0, C2, C3, C4, D0, D1, D3, F, India **Border:** a, b, c, e, f, g, i, k
Blue (Squares)	Lac A; B; E; C; EA; Fk; R8; R10; R13; Unk-Or/Red2; C-type comp.; Unk-B3; LacY1; Un6; Un10; Y4; Y13; Unk-Or6	1Tp; 2Tp; 10Tp; 11Tp; 12Tp; 15Tp; 16Tp; 18Tp; 21Tp; 22Tp; 26Tp; 28Tp; 51Tp; 52Tp; 66Tp; 67Tp; 71Tp; 73Tp; 75Tp; 78Tp; 80Tp; 81Tp; 82Tp; 83Tp; 84Tp; 86Tp; 26.285; 26.286; 26.287; 26.297; T760	**Field:** C1, C2, C3, C4, D0, D1, D2, D3, E, F, India. **Border:** a, b, c, d, e, f, g, k.	1Tp; 12Tp; 16Tp; 18Tp; 22Tp; 52Tp; 67Tp; 73Tp; 75Tp; 78Tp; 80Tp; 81Tp; 83Tp; 86Tp; 26.285; 26.287; T760.	**Field:** C0, C2, C3, C4, D0, D1, D2, D3, E, F, India, **Border:** a, b, c, d, e, f, k.

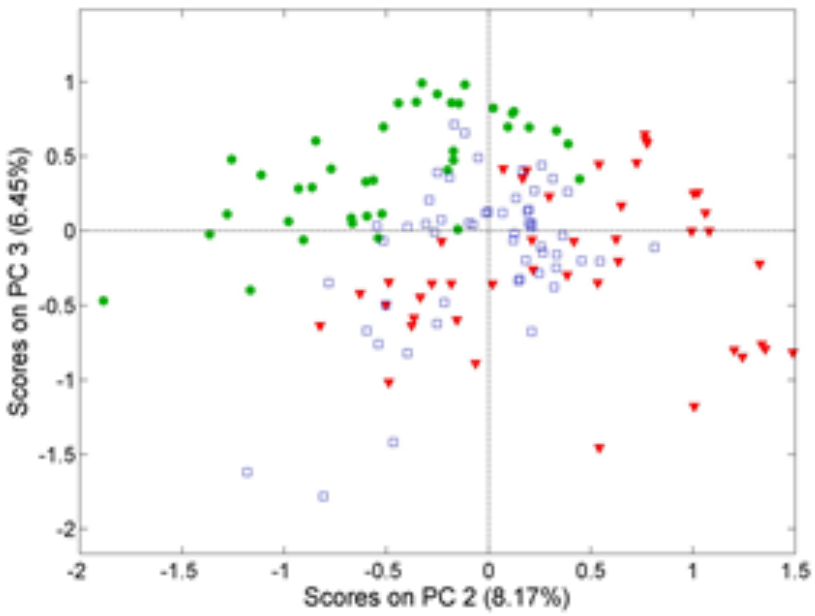
The loadings in the Blue cluster (squares) show that this group is markedly different from the rest mainly due to its composition in what refers to laccaic acid A, B, C, E, unknown red compound 13, Unknown red compound 8 and ellagic acid (figures V. 14a and V. 14b). All the samples from object 26.286 seem to occur separately from the majority of samples from this group as can be perceived from the PC1 vs PC3 scores plot (figure V. 14b). This is explained by the presence of the unknown orange-red 1 and unknown red compound 13.

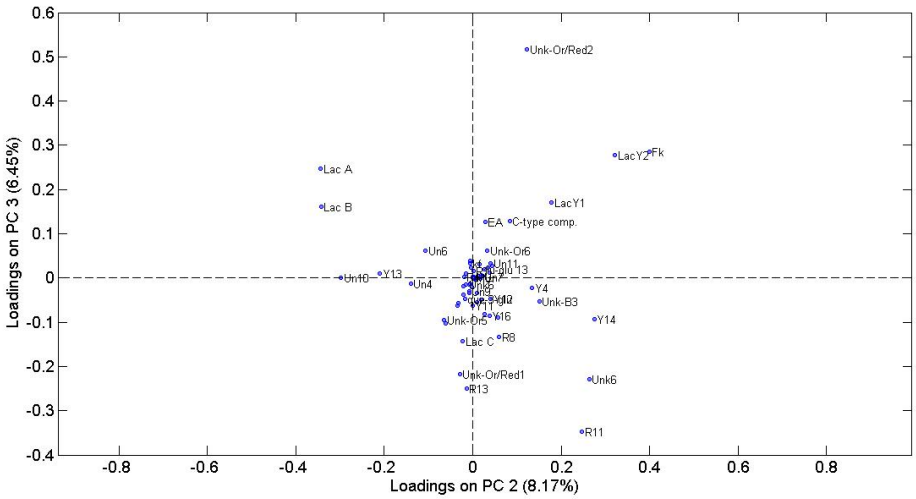
Overall it is observed that in Green cluster (circles) scores are composed by negative values in PC1 and PC2 and positive values in PC3. The analysis in the

loadings distributions, reveals that the main compounds responsible for the separation of the green cluster are unknown yellow compound 13, colorless compounds 4 and 10, unknown orang/red compound 2 and laccaic acids A and B, the latter three being the cause of separation between Red and Green clusters as seen in PC2 vs PC3 (figure V. 16). The Red cluster (triangles) on the other hand may be generally characterized by the presence of unknown yellow compounds 4, 13 and 14, colorless compounds 6 and 8, and unknown blue compound 3.

The samples from carpets comprised in the Blue cluster can be characterized primarily by the presence of laccaic acids A, B, C and E, soluble redwood component, ellagic acid, unknown orange 6, and unknown reds 8, 10 and 13. Moreover, flavokermesic acid and lac yellow 1 are also presence but having minor impact in the composition of these samples.

a)





b)

Figure V. 16: PCA from all red samples scores (a) – above and loadings (b) - below for PC2 and PC3. The elements pertaining to the "blue cluster" are represented by blue open squares for enhanced reading of the other clusters. Graph courtesy: Jorge Sarraguça.

A preliminary distinction between carpets based on the chemical composition of red historical samples is provided in the three clusters previously discussed. It demonstrates that the notion that only *Laccifer Lacca Kerr* (lac dye) was used in the reds in dyeing practices in Iran and India can be disputed.[62] With the exception of carpet 26.286 (Mughal silk), carpets with an Indian attribution can be found in all clusters. Thus, inside each cluster there are apparent larger density regions that may be further interpreted into finer groups with more defined characteristics.

Attempts to infer such groups rely on interpretation of the analysis on other colors. Nonetheless, these results disqualified the use of *Laccifer Lacca Kerr* as the principal source for red dyes on classical Iranian and Indian carpets. The previous conception of attributing dyeing practices to Iranian and Indian carpet production

[62] Nobuko Kajitani, *Floral Carpet* (Acc.no. 1916.10.8) in-house conservation work record, The Frick Collection (New York, USA), March 2006, pp. 7-23; Nobuko Kajitani, *Tree Carpet* (Acc.no. 1916.10.7) in-house conservation work record, The Frick Collection (New York, USA), March 2006, pp. 24-44; Heitor, et al., 2007; Santos, 2010; Nobuko Shibayama, *Unpublished examination and analysis report: dyes used on the Emperor's (Ass. No. 43.121.1) and 'Anhalt' (Ass. No. 46.128) carpets* from Department of Scientific Research the Metropolitan Museum of Art, (New York), 2010.

based merely on the identification of *Laccifer Lacca Kerr* (lac dye) in the reds can be can dispute.[63] The question of origin remains unclear, particularly, as carpets with an Indian attribution can be found in all clusters (see table V. 2). In each cluster however there are regions of apparent larger, which can possibly be interpreted in the future with the development of analytical techniques, into finer groups with more clear characteristics.

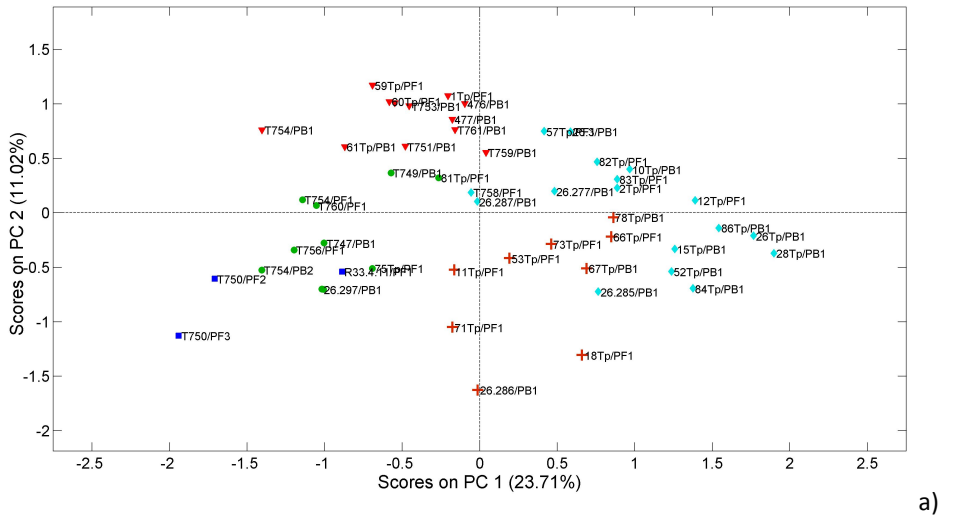
The classification of carpet production can no longer be subjected on the exclusive occurrence of chromophores (laccaic acids) attributed to lac dye. Consequently, attempts to infer groupings of objects with different origins of production must rely on the interpretation of the analysis of other colors.

Pinks

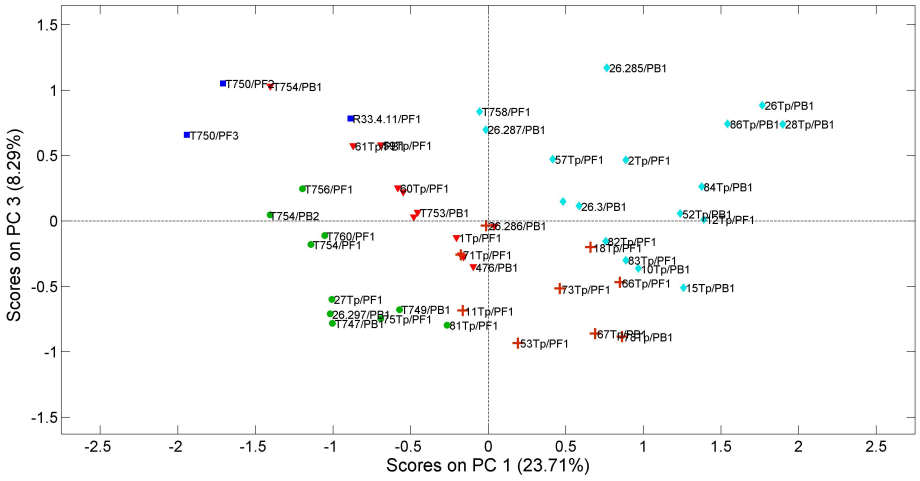
Results from pink-colored samples analyzed from 53 carpets maintained that lac-dye from *Laccifer Lacca Kerr* as well as sappanwood were used in objects with Iranian and Indian attributions. The diversity of compounds found in the pink historical samples is similar to what was found previously in red historical samples. Compounds related to the two major dye sources (lac-dye and sappanwood) seen in the red historical sample clusters can also be found in the clusters from pink historical samples.

However, the combination of known compounds (major), with additional compounds developed more groups for pink in comparison with red historical samples (see figures V. 17a and V. 17b). This suggests that pink colored samples were likely obtained from the same dye-bath used for red colors, after several uses of the bath, when concentration was reduced, or in a bath intentionally made at a lower concentration.

[63] Nobuko Kajitani, *Floral Carpet* (Acc.no. 1916.10.8) in-house conservation work record, The Frick Collection (New York, USA), March 2006, pp.7-23; Nobuko Kajitani, *Tree Carpet* (Acc.no. 1916.10.7) in-house conservation work record, The Frick Collection (New York, USA), March 2006, pp. 24-44; Heitor, et al., 2007; Santos, 2010; Nobuko Shibayama, *Unpublished examination and analysis report: dyes used on the Emperor's (Ass. No. 43.121.1) and 'Anhalt' (Ass. No. 46.128) carpets* from Department of Scientific Research the Metropolitan Museum of Art, (New York), 2010.



a)



b)

Figure III. 17: PC1 vs PC2 (a) and PC1 vs PC3 (b) scores obtained for the PCA of all pink colored samples. Scores colored according to groups resulting from HCA. Graph courtesy: Jorge Sarraguça

Figures V. 17a and V. 17b shows the PC1 vs. PC2 and PC1 vs. PC3 scores obtained from the PCA analysis of pink historical samples, with clusters colored according to the results from HCA. From the HCA analysis samples are grouped into five different clusters, when considering PCA scores corresponding to the three first principal components, as shown in figure V. 18.

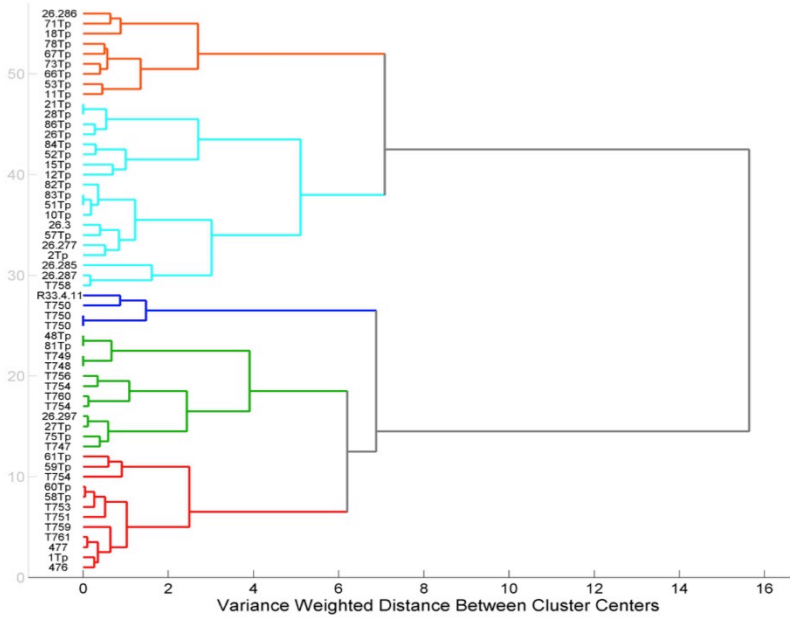


Figure V. 18: HCA dendrogram for analysis based on the scores of the 3 first principal components of PCA using all samples for pink-dyed historical samples. Ward's method, Euclidean distances. Graph courtesy: Jorge Sarraguça.

Figure V. 19 displays the PC1 vs. PC2 loadings attained from the analysis of pink historical samples recovering circa 34% of the total data variance. From the information contained in the loadings representations we can observe that a few pairs of compounds appear to be highly correlated. This is the case for laccaic acids A and B, lac yellow 1 and 2, colourless compounds 7 and 8, and the group formed by unknown red compounds 8, 10 and 13. Other compounds appear in loadings plots as important for describing variance, namely flavokermesic acid with high loading values in PC 2 and PC3 (figures V. 19 and V. 20), unknown yellow compound 13 with significant loadings in PC1, PC2 and PC3 and ellagic acid, with significant loadings in PC1 and PC3 (figure V. 20).

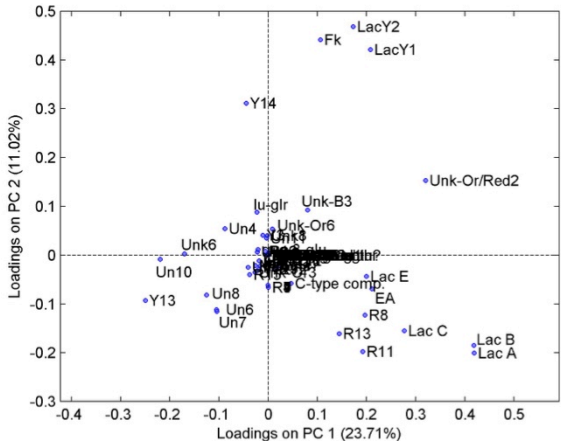


Figure V. 19: PC1 vs PC2 loadings for PCA analysis of all pink-dyed historical samples. Graph courtesy: Jorge Sarraguça.

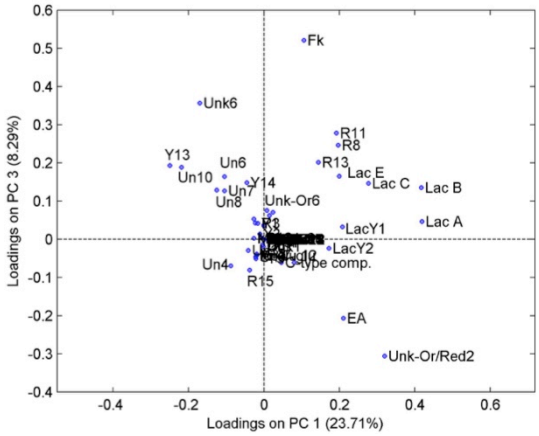


Figure V. 20: PC1 vs PC3 loadings for PCA analysis of all pink-dyed historical samples. Graph courtesy: Jorge Sarraguça.

Table V. 2 summarizes information that characterizes each cluster, namely, description of compounds (loadings) with a significant influence to the cluster assembly, accession numbers of the objects included in the cluster, along with their correspondent field and border designs.

Objects with Iranian and Indian attribution are found in the Red cluster (triangles). Analysis of the composition of the samples forming this cluster reveals that all samples have lac yellows 1 and 2, and flavokermesic acid in their composition, while soluble redwood component, unknown yellow 14 and unknown orang/red compound 1 appearing in more than 75% of the comprised samples. The scores obtained from the analysis of pink historical samples revealed that carpet T754 (see Appendix D) can be found in both Red and Green (asterisk) clusters.

Table V. 2: Distribution of carpets obtained from PCA and HCA scores results for all pink-colored historical samples (nPC=3 dist=7).

Cluster	Defining compounds	Carpets	Design	Carpets in multiple clusters	Design
Red (Triangles)	Fk; lac Y1; lac Y2; C- type comp.; Y14; unk-Or/red2	476; 477; 1Tp; 58Tp; 59Tp; 61Tp; T751; T753; T754; T759; T761	**Field:** A, C3, D0, D1, D3, G, India **Border:** f, i, g, l	T754	**Field:** D3 **Border:** f
Green (Circles)	C-type comp.; lac Y1, lac Y2; unk-or/red 2; Un4; Y13; Un 10; Y13	26.297; 27Tp; 48Tp; 75Tp; 81Tp; T747; T748; T749; T754; T756; T760	**Field:** C0, C2, C3, C4, D1, D3, E, F, India **Border:** d, f, h, j, k	T754	**Field:** D3 **Border:** f
Blue (Squares)	C-type comp.; Unk6, Y13; Un6; Un7; Un10	R33.4.11; T750	**Field:** A, C2 **Border:** f	-	-
Light-blue (Lozenges)	Lac A; lac B; lac Y1; lac Y2; c-type comp.; fk; Unk or/red2	2Tp; 10Tp; 12Tp; 15Tp; 21Tp; 26Tp; 28Tp; 51Tp; 52Tp; 57Tp; 82Tp; 83Tp; 84Tp; 86Tp 26.277; 26.285; 26.287; 26.300; T758	**Field:** C0, C1, C2, C3, C4, D0, D2 **Border:** a, b, c, d, e, f, g, i	-	-
Orange (Plus)	Lac A, Lac B; C-type comp.; EA; Lac Y1; Unk-Or/Red2	11Tp; 18Tp; 53Tp; 66Tp; 67Tp; 71Tp; 73Tp; 78Tp; 26.286	**Field:** C2, C4, D3, F, India **Border:** c, e, h, k	-	-

Objects included in the Green cluster (circles) have Indian and Iranian attribution. This cluster appears to be rather heterogeneous regarding sample compositions, with no compound being common to all samples. Nevertheless, soluble redwood component is found in over 75% of the samples, while lac yellow 1 and 2 and unknown orange/red compound 2 are found in 50 to 75% of the samples. The colorless compounds 4 and 10 and unknown yellow compound 13 were identified in only 25%-50% of the samples. In this cluster, with colorless compounds 3, 8 and 9, unknown red compounds 15 and 16, apigenin-7-glucoside, luteolin-glucoside 12, unknown yellow compound 11, kaempferol-3-β-glucopyroside, flavokermesic acid and quercetin-3-glucoside were identified in under 25% chromatograms and laccaic acids A and B are absent.

Compounds with negative loadings in PC1 play a significant role in the characterization of carpets within the Blue cluster (squares). Thus, compound unknown yellow 13 and colorless compounds 6, 7 and 10 (all present in more than 75% of the samples) have a greater influence separate the only two objects in this cluster, both of Iranian attribution, T750 and R33.4.11 (see Appendix D). All samples of this cluster contain soluble redwood component and unknown compound 6. Significant is the total absence of any lac-dye products in the composition of these pink samples.

The Light-blue cluster (lozenges) is comprised exclusively of 'Indo-Persian' objects (table V. 2). From composition analysis of these samples it was observed that all samples contained laccaic acids A and B, lac yellow 1, while lac yellow 2, flavokermesic and unknown-orang/red compound 2 are present in over 75% of the samples. Moreover, laccaic acids E and C, ellagic acid, unknown red compounds 8, 11 and 13 are included in 25%-50% of the samples.

The objects comprised in the Orange cluster (plus) exhibited a significant influence from laccaic acid A (present in all samples), laccaic acids B and C, soluble redwood component (present in over 75% samples. Additionally, ellagic acid, lac yellow 1 and unknown orang/red compound 2 were identified in in 50-75% of the samples, while lac yellow 2 only in 25-50% of samples (see table V. 2). Present in lower percentage are unknown red compounds 1, 4, 7, 9, 11 and 13, laccaic acid C, unknown orange compounds 2 and 3, and unknown blue compound 3.

The majority of the colorless and unknown compounds identified in the pink samples have been previously identified in red historical samples. Although, it is not possible to associate them with specific dye sources, these can be subsequent products from different fiber or dyeing parameters.[64] The analysis of pink samples disclosed the potential of learning about their minor compounds - particularly unknown blue compound 3 - to disclose further information to enable their

[64] Serrano, et al., 2015, p. 120.

association with specific dye-sources, or simply identify them as products of fibers or dyeing procedures.

Yellows

Regarding the analysis of the yellow historical samples the results for all 59 carpets are displayed in figure V. 21 and V. 22. The scores in PC1 vs PC2 (figure V. 21) show a clear separation of the scores into three large groups. The colors used to distinguish different clusters (figures V. 21 and V. 22) correspond to the colors identifying the clusters defined by Hierarchical Cluster Analysis (HCA) in figure V. 23

The large group along PC1 may be subdivided into 3 clusters, while the other 2 groups remain as single clusters. Green, Blue and light blue clusters are separated along the PC1 axis, while the orange cluster requires additional information recovered in PC2, and the red cluster requires information contained into PC3 to be clearly separated. The classification of the samples into groups leading to attribution in the PCA scores plots was based on a HCA procedure using Ward's method, recovering approximately 43% of the total variance of the data.

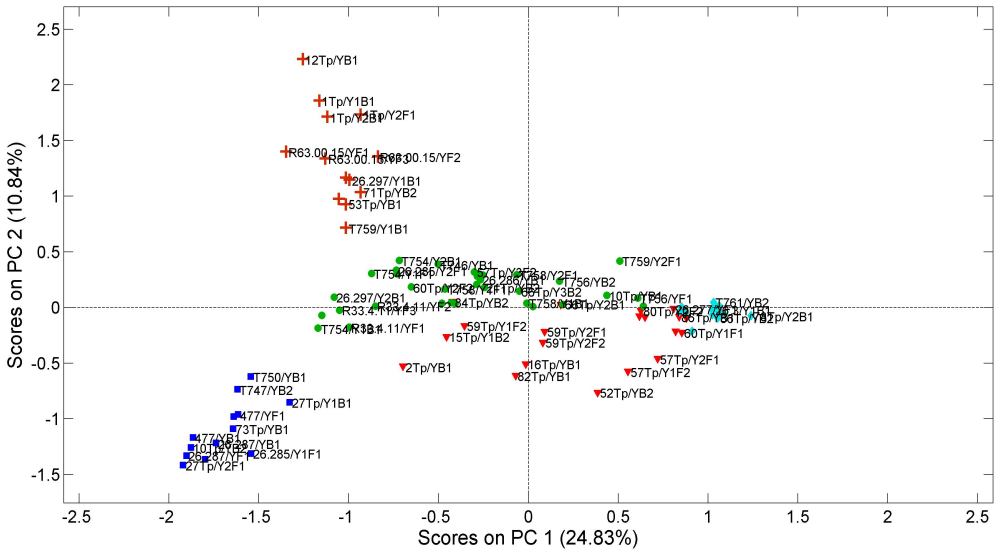


Figure V. 21: The scores plot is colored by groups resulting from HCA analysis for PC1 vs PC2.Graph courtesy: Jorge Sarraguça.

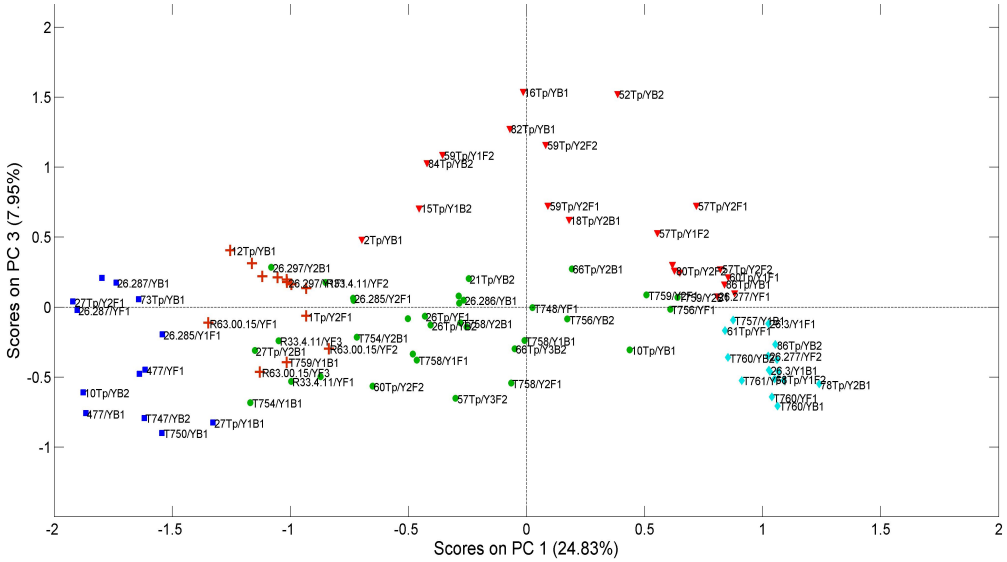


Figure V. 22: The scores plot is colored by groups resulting from HCA analysis for PC1 vs PC3 for all yellow samples. Graph courtesy: Jorge Sarraguça.

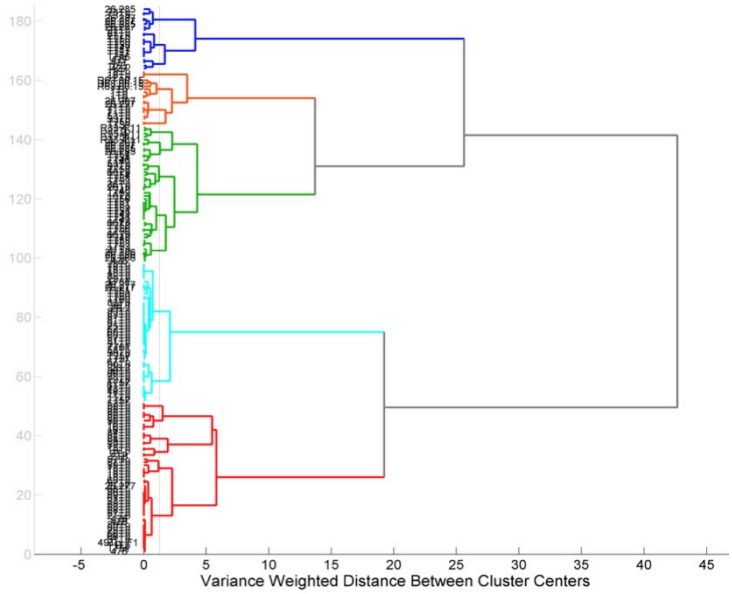


Figure V. 23: Dendrogram from HCA of all yellow samples. Five clusters were selected using Ward's method based on Euclidean distances exceeding 6. The HCA was performed using the scores for the 3 first principal components. Graph courtesy: Jorge Sarraguça.

Figure V. 23 shows the dendrogram with five groups resulting from a variance-weighted distance between cluster centers exceeding 6. It classifies the yellow historical samples into 5 different types of chemical composition, according to the distribution of loadings in figures V. 24 and V. 25. The loadings relative to PC1 and PC2 show that the variables recovered on the two first principal components, corresponding to 34% of the total variance of the data (figure V. 24).

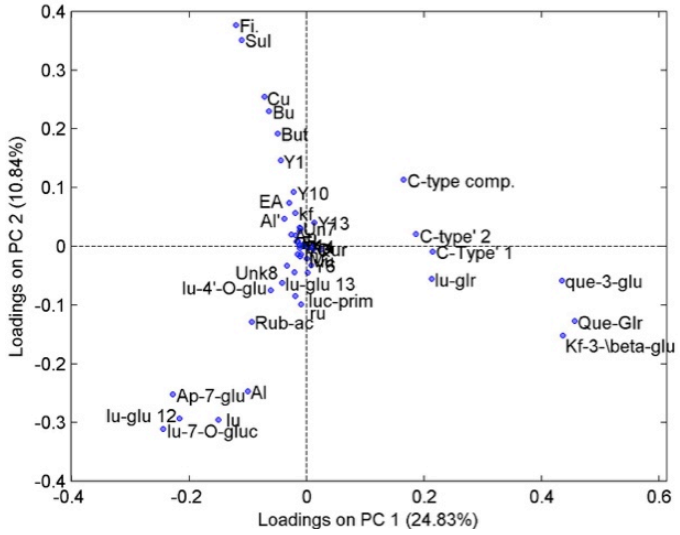


Figure V. 24: Loadings for PC1vs PC2 relative to PCA analysis for all samples of yellow samples. Graph courtesy: Jorge Sarraguça.

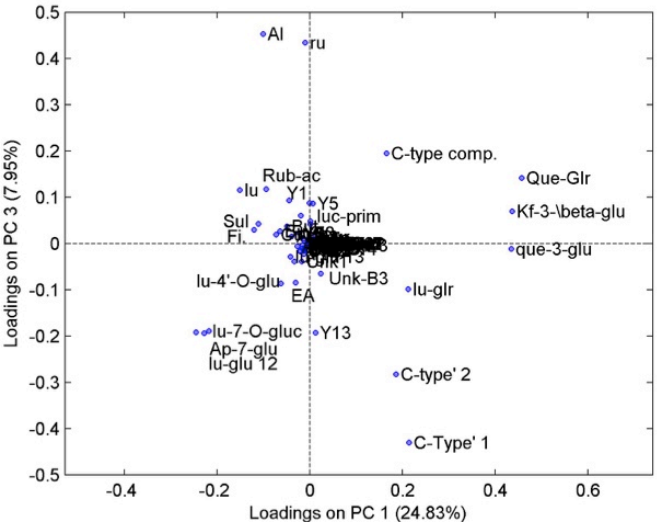


Figure V. 25: Loadings for PC1 vs PC3 relative to PCA analysis for all samples of yellow samples. Graph courtesy: Jorge Sarraguça.

Table V. 3 assigns the carpets into the different clusters, each characterized by defining compounds with a significant influence to the cluster assembly, accession numbers of the comprised objects, along with their correspondent field and border designs. The Orange cluster is essentially characterized by the existent fisetin in all samples of the cluster. Sulfuretin and soluble redwood component are present in over 75% of samples, while curcumin is found in 50%-75% (table V. 3).

Finally, butein, butin and unknown yellow compounds Y1 occur in 25%-75%, and minor compounds in less than 25% of cluster samples.

The markers indicate that more than one yellow dye-source was used, namely, turmeric and young fustic. However, butein is present in young fustic, and butin and butein are also known to be present in flame of the forest. Hence, it is likely that these dyestuffs could have been together in the dye-bath. Whereas turmeric and flame of the forest are well reported as dyestuffs in India, young fustic is known to occur in areas ranging from Turkey to China, including the Himalayas (Nepal) on the eastern border of India. Therefore, carpet workshops in India would have had relatively easy access to it. In fact, with the exception of carpet T759 from MNMC collection (see Appendix D), all objects in the Orange cluster have an Indian attribution.

The Blue cluster (squares) is principally characterized by luteolin-7-O-glucoside, luteolin-glucoside 12, apigenin-7-glucoside (identified in all samples classified into the cluster cluster) and luteolin (present in more than 50% of the samples). Moreover, marker compounds such as alizarin, luteolin-4'-O-glucoside, soluble redwood component and ruberythric acid are present in 25-50% of samples (Appendix H). This specific marker combination suggests the use of weld or flax-leave daphne and madder (possibly *Rubia tinctorium* L.), all identified as dyestuffs from Mediterranean and central Asian regions.

However, the presence of luteolin-glucoside 12 indicates that other possibilities cannot be excluded; therefore the need of further investigation on yellow dye-sources remains. Results suggest that carpets from the Blue cluster (table V. 3) are likely to have been produced by a single workshop or workshops from a localized production. Their design types range from the early Field A to Field *C*, including its last derivations C4.

The Red cluster (triangles) encompasses 24 objects in which quercetin-3-glucoside**,** kaempferol-3-ß-glucopyroside, quercetin-glucoronide and soluble redwood component are common markets to more than 75% of the samples, while luteolin-glucoronide, alizarin, and rutin are identified in 25%-50% (table V. 3).

Approximately 21 minor compounds were identified in the samples though each being present in less than 25% of the samples.

Samples in the Green cluster (circles) are characterized by a combination of soluble redwood component (present in 50%-75% of samples) with unknown yellow compound 13, ellagic acid, quercitrin, kaempferol-3-β-glucopyroside and quercetin-3-glucoside occurring in 25%-50% of all samples. It comprises objects with fields varying from the earlier field types (Field A - *'Vine scroll with Animals'*) to the latest developments from the design (Field D3 – *Large 'Indo-Persian' design with Sickle leaves – Geometric composition*). The only exceptions are carpet 476 (see Appendix D), in which the field falls in the Field G (and three objects from India, namely, carpets 26.286, 26.297 and 53Tp (see Appendix D).

In contrast, yellows from Orange cluster (plus) are defined by a combination of fisetin, present in all samples, soluble redwood component, sulfuretin and curcumin (50%-75%), butin, sulfuretin-like and unknown yellow compound 14 (25%-50% of samples). These compounds suggest that sappanwood, weld and/or flax-leave daphne, together with other dyestuff belonging to *Nonea* sp., *Euphorbia* sp., *Papaver* sp. and *Populus* sp. were used to obtain a yellow color. Unfortunately, due to the possibility of several sources the presence of ellagic acid cannot be associated with a specific dyestuff.

Table V. 3: Distribution of carpets obtained from PCA and HCA scores results for all yellow-colored historical samples. (nPC=3 dist=10)

Cluster	Defining compounds	Carpets	Design	Carpets in multiple clusters	Design
Red (Triangles)	Al; C-type comp; Que-Glr; Kf-3-β-glu; lu; que-3-glu	476; 2Tp; 11Tp; 15Tp; 16Tp; 18Tp; 21Tp; 28Tp; 49Tp_F1; 51Tp; 52Tp; 57Tp; 58Tp; 59Tp; 60Tp; 61Tp; 66Tp; 75Tp; 80Tp; 82Tp; 84Tp; 86Tp; T751; 26.277	**Field:** C4, C2, C1, D1, D0, G, F, D2 **Border:** f, c, b, Papaver sp., e, d, k, g, i , l	476, 11Tp, 21Tp, 51Tp, 57Tp, 58Tp, 60Tp, 61Tp, 66Tp, 75Tp, 80Tp, 86Tp, 26.277, T751	**Field:** G, C2, D1, C4, D0, F, D2 **Border:** c, Papaver sp., d, k, f, i
Green (Circles)	C-type comp.; Y13; EA; kf-3-β-glu; que-3-glu	476; 10Tp; 21Tp; 26Tp; 27Tp; 53Tp; 57Tp; 60Tp; 66Tp; R33.4.11; 26.285; 26.286; 26.297; T746; T748; T749; T751; T753; T754; T756; T758; T759	**Field:** A, G, C2, D1, C3, C4, B, D0, D3, India **Border:** a, l, f, Papaver sp., j, g, i	476, 10Tp, 21Tp, 27Tp, 53Tp, 57Tp, 60Tp, 66Tp, T746, T751, T759, 26.285, 26.297	**Field:** C2, D1, G, C4, B, D0, India **Border:** f, Papaver sp., l, i
Blue (Squares)	Lu; Lut-7-O-glu, lut-glu 12; ap-7-glu; Al; rub-ac; c-type comp.; lut-4'-O-glu	477; 10Tp; 27Tp; 73Tp; T746; T747; T750; 26.285; 26.287	**Field:** A, C2, C3, B, C0, C4 **Border:** l, f, a	10Tp, 27Tp, 26.285, T746	**Field:** C2, C4, B **Border:** f, a
Light blue (Lozenges)	kf-3-β-glu; que-3-glu; que-glr; C-type comp.; C-type'1; C-type' 2	11Tp; 22Tp; 48Tp; 51Tp; 57Tp; 58Tp; 60Tp; 61Tp; 67Tp; 75Tp; 78Tp; 80Tp; 81Tp; 83Tp; 86Tp; T757; T760; T761; 26.277; 26.300	**Field:** C2, D0, F, G, D3, D2, E, C3, D1 **Border:** c, f, k, d, e, Papaver sp., g, i	11Tp, 51Tp, 57Tp, 58Tp, 60Tp, 61Tp, 75Tp, 80Tp, 86Tp, 26.277	**Field:** C2, D0, D2, G **Border:** c, d, f, l, k
Orange (Plus)	Fi; C-type comp.; Sul; Cu; bu; Sul'; Y14	1Tp; 12Tp; 53Tp; 71Tp; T759; 26.297; R63.00.15	**Field:** D1, India **Border:** i	53Tp, 26.297, T759	**Field:** D1, India **Border:** i

In the Light blue cluster, on the other hand, all samples have quercetin-3-glucoside, quercetin-glucoronide and kaempferol-3-β-glucopyroside, and soluble redwood component and soluble redwood component' 1 in a large part of samples (over 75%). Additional compounds are identified: soluble redwood component' 2 (50-75% of all samples), luteolin-glucoronide (25-50%), and ellagic acid, unknown blue compound 3 and unknown yellow compound 3 in less than 25%. These results

indicate that carpets 48Tp, 67Tp and 75Tp, sharing the same border (border k - *Pomegranate palmettes alternating with cypress trees)* and field *(F - 'Tile Pattern' design – Quatrefoil Arabesque*) are likely products from the same workshop.

The yellow samples in the Red, Blue and Light blue clusters correspond to carpets attributed to Early Safavid and 'Indo-Persian', showing that sappanwood was used in both cases. Looking closely at the precise combinations of markers found, it is evident that more than one dyestuff was used to obtain yellow-dyed fibers (see figure 2 in Appendix I). Overall, these results confirm the existence of several dyeing traditions, while supporting their association to distinct geographical locations, namely Iran and India. The yellow historical samples in the Orange cluster (plus) revealed that for 'Indian' carpets more than one yellow dye-source was used. Hence, owing to the presence of their major chromophores turmeric, young fustic (see figure 1 in Appendix I) and flame of the forest were identified as distinctive dye-sources present in yellow historical samples belonging to these carpets.

Oranges

The analyses of the orange samples from 32 carpets are shown in figures V. 26 and V. 27 and are colored according to the groups obtained by Hierarchical Cluster Analysis (HCA) (figure V. 28). The HCA suggests that samples of orange dyes forming the present dataset may be clustered into 5 groups, using approximately 53% of the total variance of data from PCA.

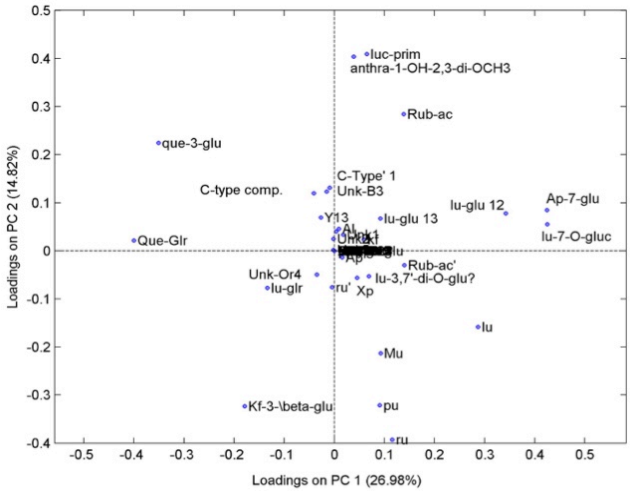


Figure V. 26: Loadings for PC1vs PC2 are relative to PCA analysis for all samples of orange color. Graph courtesy: Jorge Sarraguça.

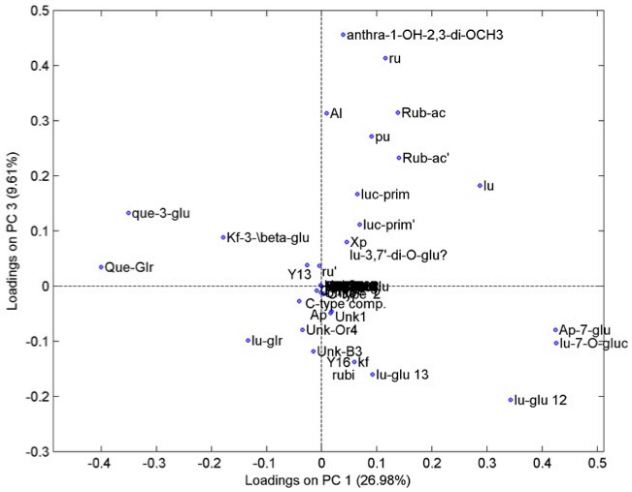


Figure V. 27: Loadings for PC1 vs PC3 are relative to PCA analysis for all samples of orange color. Graph courtesy: Jorge Sarraguça.

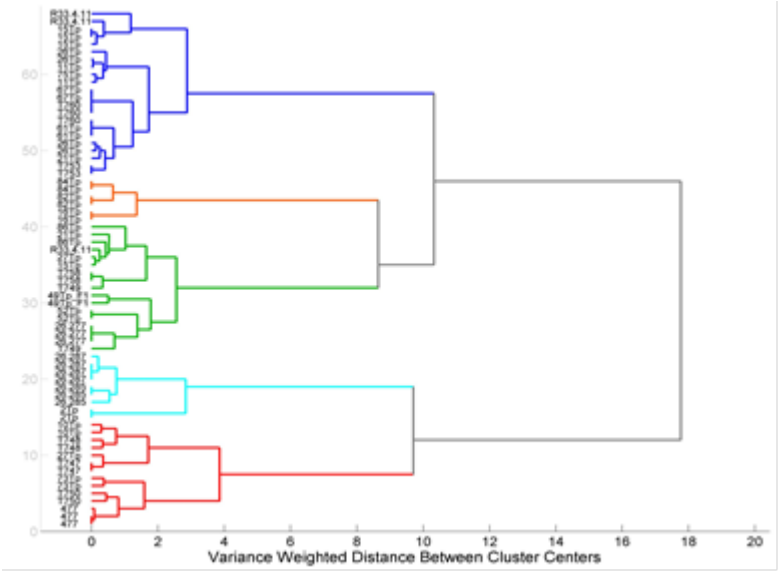


Figure V. 28: HCA dendrogram for all orange-colored historical samples. Graph courtesy: Jorge Sarraguça.

Figures V. 29 and V. 30 present the scores colored according with the subsequent groups from HCA analysis for PC1 vs PC2 (a) and PC1 vs PC3 (b) for all orange samples.

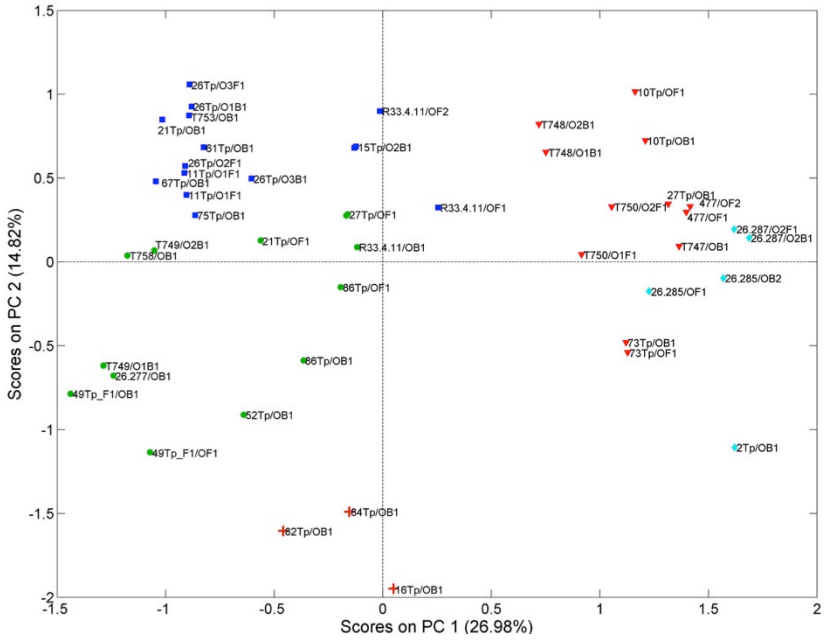


Figure V. 29: The scores plot is colored by groups resulting from HCA analysis for PC1 vs PC2 comprising all orange samples. Graph courtesy: Jorge Sarraguça.

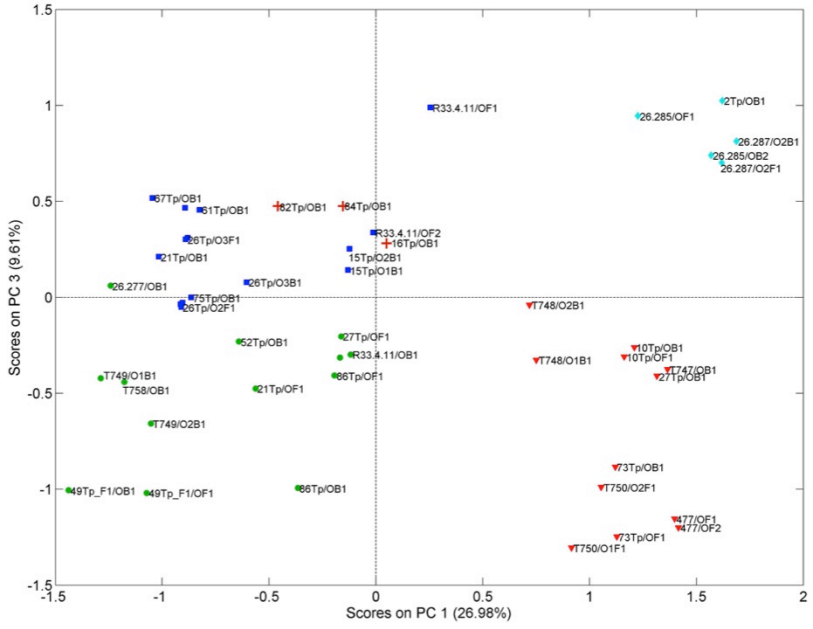


Figure III. 30: The scores plot is colored by groups resulting from HCA analysis for PC1 vs PC3 comprising all orange samples. Graph courtesy: Jorge Sarraguça.

This classification into five groups is summarized in table V. 4, which characterizes each cluster and the existing compounds with the most significant influence to the cluster assembly. Moreover, the accession numbers of the objects

included in the cluster, along with their correspondent fields and border designs are also presented in the table.

Table III. 5: Distribution of carpets obtained from PCA and HCA scores results for all orange-colored historical samples (nPC=3 dist=3).

Cluster	Defining compounds	Carpets	Design	Carpets in shared clusters	Design
Red (Triangles)	Ap-7-glu, lu-7-o-glu, lu-glu-12, Rub-ac, Luc-prim.	477; 10Tp; 27Tp; 73Tp; T747; T748; T750	**Field:** A, C0, C2, C3 **Border:** f, l	27Tp	**Field:** C2 **Border:** f
Green (Circles)	c-type comp., Que-glr, luc-prim, al, que-3-glu	15Tp; 21Tp; 27Tp; 49Tp_F1; 52Tp; 86Tp; R33.4.11; 26.277; T749; T758	**Field:** A, C1, C2, C3, D0, D1, D2 **Border:** e, f, g, h, i	15Tp; 21Tp; 27Tp; R33.4.11	**Field:** A, C1, C2, D1 **Border:** f, h
Blue (Squares)	Luc-prim, al, Que-3-glu, rub-ac, anthra-1-OH-2,3-di-OCH3, Que-Glr, c-type comp.	11Tp; 15Tp; 21Tp; 26Tp; 61Tp; 67Tp; 75Tp; R33.4.11; T753; T760	**Field:** A, C1, C2, C3, D0, D1, F **Border:** c, f, h, k	15Tp; 21Tp; R33.4.11	**Field:** A, C1, D1 **Border:** f, h
Light blue (Lozenges)	Lu-7-o-glu, lu, ap-7-glu, Rub-ac', luc-prim, c-type comp al, ru, anthra-1-OH-2,3-di-OCH3	2Tp; 26.285; 26.287	**Field:** C0, C4 **Border:** a, f	-	-
Orange (Plus)	al, ru, pu, kf3-beta-glu	16Tp; 82Tp; 84Tp	**Field:** C1, D0, D1 **Border:** b, f, g	-	-

The Red cluster (triangles) is composed of seven carpets (see table V. 5) with apigenin-7-glu and luteolin-7-O-glucoside present in all samples, while luteolin-glucoside 12 ruberytric acid and lucidin primveroside are present in over 75% of the samples, being the most important variables for group characterization. Additionally, kaempferol-3-ß-glucopyroside found in the third quadrant, suggests an inverse correlation with the previous mentioned variables. Thus, is absent from the composition that characterizes oranges samples in this cluster.

The Light blue cluster (lozenges) corresponds to the location of luteolin, ruberytric acid-like' and lucidin primveroside compounds that are present in all

samples. Additionally, also present in all samples are luteolin-7-O-glucoside, alizarin, and rutin. Soluble redwood component and anthraquinone-1-OH-2,3-di-OCH_3 were also identified in over 75% of the samples of the cluster.

In Blue cluster (squares) all samples were observed to contain lucidin primveroside and alizarin, while ruberytric acid, anthraquinone-1-OH-2,3–di-OCH_3, quercetin-3-glucoside were identified in over 75% of the samples. In the third quadrant is located luteolin-glucoronide, which together with soluble redwood component, lucidin primveroside-like, rutin-like, and xanthopurpurin is significant to characterize oranges in carpets falling into the Green cluster (circles).

The Orange cluster (plus) separates from all others in PC2, from where, oranges from this group would be expected to be associated with the presence of rutin, purpurin, kaempferol-3-ß-glucopyroside. Together with alizarin all mentioned compounds were identified in all samples in the Orange cluster. Objects belonging to the orange and light blue clusters were not found in other clusters (see table V. 5). This suggests that these carpets likely share a unique compound mixture, perhaps from a common workshop. Moreover, considering the particular orange samples from carpets belonging to the Light blue cluster seems likely that luteolin was used in smaller concentrations, resulting in a deeper and intense orange color.

All samples analysed revealed that oranges were obtained exclusively from a mixture of roots of the madder plant with one or more yellow dye sources. From these results one can recognize variances in dyeing recipes exist based on the markers associated several yellow-dye sources. As for the red-source use in the oranges seems clear that *Rubia akane* was not use in any of the objects, due to the absence of 6-hydroxyrubiadin its major chromophore.

Based on presence of alizarin (alone or in combination with other compounds) and its reported usage in Iranian and Indian regions, *Rubia tinctorum* seems to be the most likely madder specie used. It is not yet possible to attain more accurate distinctions of madder species used based on reliable markers.[65] However,

[65] Mouri, 2012.

the use of madder as a red dye source in orange colors has been suggested as an indicator of Iranian pallete for Islamic carpets.[66] These results seem to corroborate and reinforce this perception as orange was only found in carpets with Iranian attribution.

The existence of orange in only 32 objects together with the restraints of reliably determine species of *Rubia* spp. reveal that madder and, therefore, the oranges are still a limitant factor for the purposes of geographical attributions. Yet, the yellow dye sources used in the oranges represent a significant information to establish not only different dyeing tradition, but also potential location.

Browns

The results regarding the analysis of the brown historical samples collected from 48 carpets are shown in figure V. 31. The scores in the PC1 vs PC2 relative to PCA using all brown colored samples recover approximately 35% of the total variance of the chemical composition of the samples.

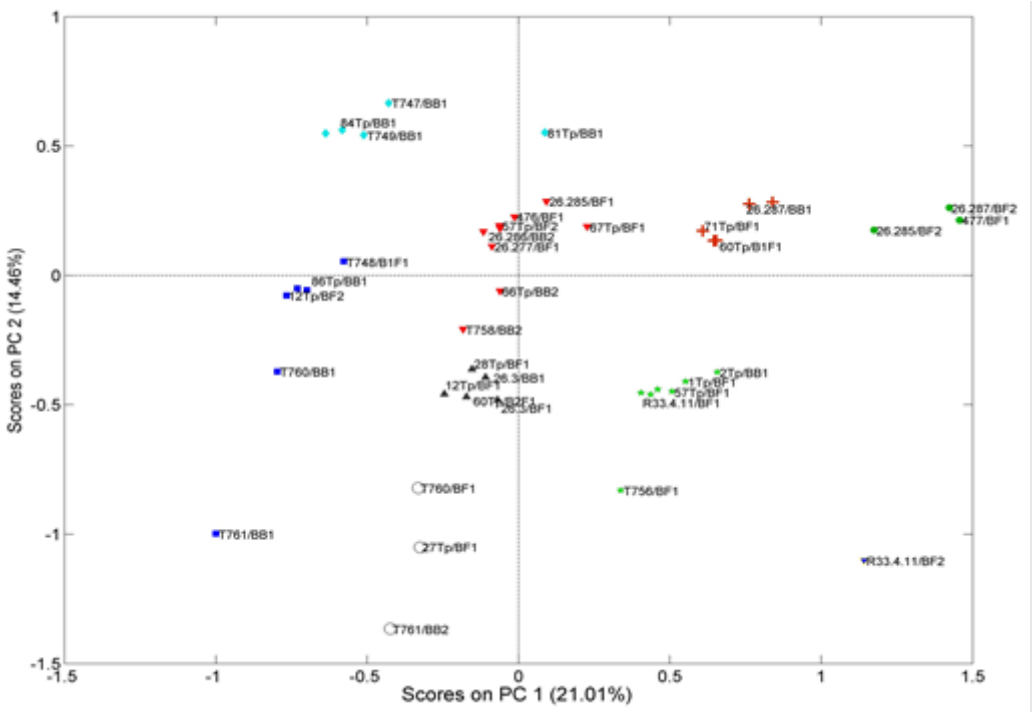


Figure V. 31: The scores plot is colored by groups resulting from HCA analysis for PC1 vs PC2

[66] Heitor, et al., 2007; Arminho, et al. 2008; Santos, 2010.

comprising all brown samples. Graph courtesy: Jorge Sarraguça.

Three large groups are essentially separated along PC1. The first group, with Blue cluster (squares) and Orange (plus sign) situated along the first principal component axis, is separated from two others. One located along the first and third quadrant including the White (circles), Black (triangles) and Red (triangles) clusters. A third group of clusters includes the Green (stars), Light blue (lozenges) and Green (circles). Finally, the Yellow cluster is comprised by a single object, carpet R33.4.11 (see Appendix D), due to its distinct compound combination such as apigenin-7-glucoside, alizarin, 2,6-di-OH-anthraquinone (2,6-di-OH-anthr) and quercetin-3-glucoside, suggesting the presence of a mixture of madder and yellow dye-sources compounds, possibly *Nonea* sp., *Euphorbia* sp. or *Papaver* sp. In a first observation, the organization into three large groups is apparently similar to what resulted from the analysis of the red historical samples. However, the components responsible are generally not related in the two cases as shown in figure V. 32.

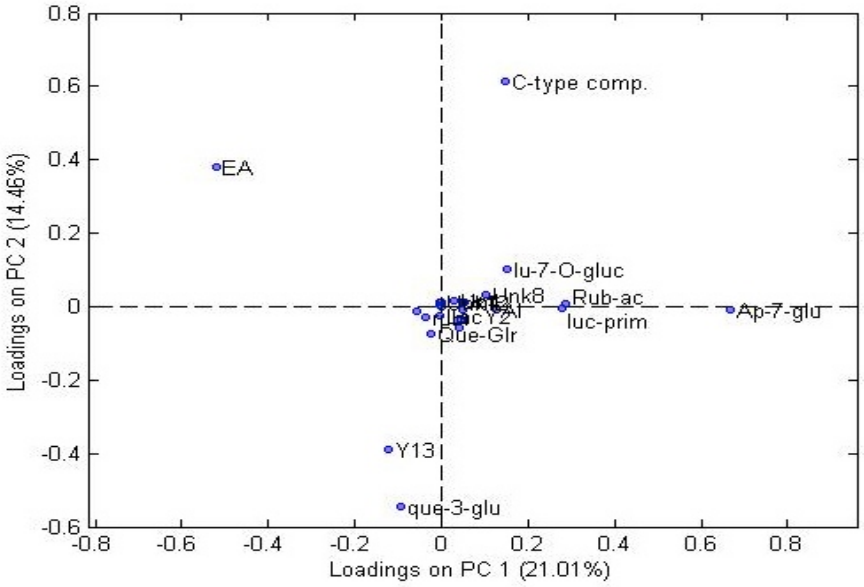


Figure V. 32: Loadings for PC1 vs PC2 comprising PCA analysis for all historical samples of brown color. Graph courtesy: Jorge Sarraguça.

The most important compounds in describing variability of the brown historical samples are soluble redwood component, ellagic acid, apigenin-7-glucoside, yellow compound 13, quercetin-3-glucoside, and to a smaller extent

luteolin-7-O-glucoside and lucidin-primveroside, being the chemical compounds showing the larger loading values on all first three principal components in PCA as (figure V. 32).

The Hierarchical Cluster Analysis (HCA) of the sample composition performed based on the score results of PCA. In a preliminary examination of the dendrogram, it is apparent that the samples could be grouped into nine clusters selected using Ward's method based on Euclidean distances exceeding 5. It is observed that in a general examination of composition the clusters colored in figure V. 33, can be separated in two large categories, based on the presence or absence of ellagic acid in Blue and Light blue clusters.

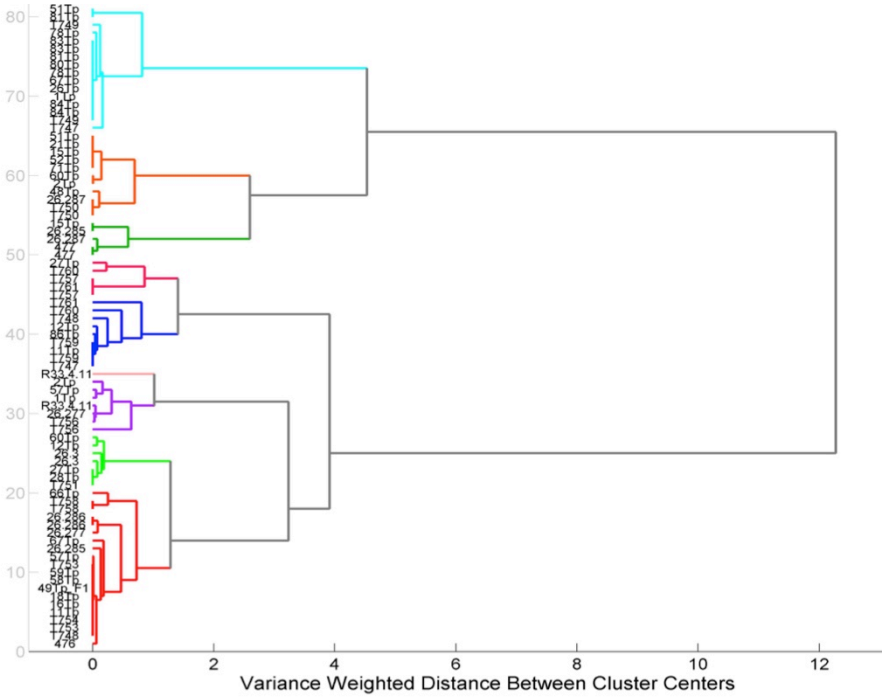


Figure V. 33: Dendrogram from HCA of all brown historical samples. The nine clusters were selected using Ward's method based on Euclidean distances exceeding 5. Graph courtesy: Jorge Sarraguça.

Table V. 5 summarize the description of compounds with a significant influence to the cluster assembly, accession numbers of the objects included in the cluster, along with their correspondent field and border designs. The clusters Light blue (lozenges) and Blue (squares) are characterized by the presence of ellagic acid in all samples. Samples from Light blue cluster (lozenges) may contain one or more of the following compounds: apigenin-7-glucoside, soluble redwood component,

luteolin-7-glucoside, alizarin and kaempferol-3-β-glu, while samples in Blue cluster (squares) contain soluble redwood component, luteolin-7-glucoside, rubiadin, yellow compound 13, quercetin-3-glucoside and quercetin-glucoronide. The objects in the Red cluster (triangles) all contain soluble redwood component and apigenin-7-glucoside, (table V. 5).

Table V. 5: Distribution of carpets obtained from PCA and HCA scores results for all brown-colored historical samples (nPC=3 dist=5).

Cluster	Defining compounds	Carpets	Design	Carpets in shared clusters	Design
Red (Triangles)	C-type comp., Ap-7-glu	476; 11Tp; 16Tp; 18Tp; 49Tp_F1; 57Tp; 58Tp; 59Tp; 66Tp; 67Tp; 26.277; 26.285; 26.286; T748; T753; T754; T758	**Field:** C2, C3, C4, D0, D1, D2, D3, F, G, India **Border:** b, c, e, f, g, h, i, k, l	11Tp; 57Tp; 67Tp; 26.277; 26.285; T748	**Field:** C2, C4, D2, F, G **Border:** c, f, i, k
Green (Circles)	C-type comp., Ap-7-glu, Rub-ac, luc-prim.	477; 15Tp; 26.277; 26.287	**Field:** A, C0, C1, D2 **Border:** a, f, i, l	26.285; 15Tp; 26.287	**Field:** C0, C1, C4 **Border:** a, f
Blue (Squares)	EA, c-type comp., lu-7-O-glu, rubi, Y13, que-3-glu, Que-glr, kf-3-β-glu	11Tp; 12Tp; 86Tp; T747; T748; T759; T760; T761	**Field:** C0, C2, D0, D1, India **Border:** c, f, g, h, i	11Tp; 12Tp; T747; T748; T760; T761	**Field:** C0, C2, D1, India **Border:** c, f, g, h
Light Blue (Lozenges)	EA, C-type comp.	1Tp; 26Tp; 51Tp; 67Tp; 78Tp; 80Tp; 81Tp; 83Tp; 84Tp; T747; T749	**Field:** C0, C1, C2, C3, D0, D2, D3, E, F, India **Border:** d, e, f, k	1Tp; 51Tp; 67Tp; T747	**Field:** C0, C2, F, India **Border:** d, f, k
Orange (Plus)	C-type comp., Ap-7-glu, lu-7-O-glu, fk, Un4, que-3-L- Rh	2Tp; 15Tp; 21Tp; 48Tp; 51Tp; 52Tp; 60Tp; 71Tp; T750; 26.287	**Field:** C0, C1, C2, C4, D0, D1, F, G, India **Border:** a, d, f, h, k	2Tp; 15Tp; 51Tp; 60Tp; 26.287	**Field:** C0, C1, C2, C4, G **Border:** a, d, f
Black (Triangles)	C-type comp., lu-4'-O-glu, LacY1, que-3-glu, LacY2, Rubi, Fk	12Tp; 27Tp; 28Tp; 60Tp; 26.300; T751	**Field:** C2, D0, G, India **Border:** c, f	12Tp; 27Tp; 60Tp	**Field:** C2, G, India **Border:** f
Green (Stars)	Ap-7-glu, C-type comp., lu-7-O-glu, fk,	1Tp; 2Tp; 57Tp; R33.4.11; 26.277; T756	**Field:** A, C4, D2, G, India	1Tp; 2Tp; 57Tp; 26.277;	**Field:** A, C4, D2, G, India

	que-3-glu, kf-3-β-glu, Y13, Que-Glr, que-3-L-Rh		**Border:** f, i, j	R33.4.11	**Border:** f, i
White (Circles)	Y13, Que-3-glu, Que-Glr	27Tp; T757; T760; T761	**Field:** C2, C3, D1 **Border:** f, g, h	27Tp; T760; T761	**Field:** C2, D1 **Border:** f, g, h
Yellow (Triangle)	Ap-7-glu, Rub-ac, luc-prim, anthr-1,3-di-OCH3, 2,6-di-OH-anthr, Al, que-3-glu	R33.4.11	**Field:** A **Border:** -	R33.4.11	**Field:** A **Border:** -

All remaining clusters, namely, Green (circles), Green (stars), Orange (plus), Black (triangles), White (circles) and Yellow (triangle) clusters are characterized by the absence of ellagic acid. The Orange cluster (plus) corresponds to samples that contain soluble redwood component and apigenin-7-glucoside, with luteolin-7-glucoside, colorless compound 4 and quercetin-3-L-rhamninoside.

The characterization of objects included in the Green cluster (circles) has an expressed influence of soluble redwood component, apigenin-7-glucoside, ruberythric acid and lucidin primveroside compounds. In addition the presence of compounds such as alizarin, yellow compound 12, unknown red compound 8, luteolin-7-glucoside, colorless compound 2 and luteolin-4'-O-glucoside can also be present in these samples.

The samples from clusters located in the fourth quadrant are characterized by the presence of apigenin-7-glucoside and the absence of both soluble redwood component and ellagic acid. The Green cluster (stars) is composed by samples in which apigenin-7-glucoside is major compound found in several combinations of the following components: soluble redwood component, luteolin-7-O-glucoside, flavokermesic acid, quercetin-3-glucoside, kaempferol-3-β-glucopyroside, unknown yellow 13, quercetin-glucoronide, quercitrin, quercetin-3-L-rhamninoside.

The object enclosed by the Black cluster (triangles) near the origin in the third quadrant have no particular composition. All the samples are composed by different combinations of luteolin-4'-O-glucoside, soluble redwood component, rubiadin, flavokermesic acid, quercetin-3-glucoside and quercitrin. In addition, lac

yello 1 and 2 were found to be present exclusively in the carpet 26.300 (see Appendix D), together with luteolin-4'-O-glucoside, soluble redwood component, flavokermesic and quercetin-3-glucoside.

Finally, the presence of yellow compound 13, quercetin-3-glucoside, quercetin-glucoronide and the absence of soluble redwood component, ellagic acid or apigenin-7-glucoside characterize the objects included in the White cluster (circles). This suggests the use of *Nonea* sp., *Euphorbia* sp., *Papaver* sp. or *Prangos* sp. as dye-sources possible used in the brown samples of these carpets. Together with the Yellow cluster, objects in the White Cluster do not include any Indian carpets. None of these dye sources is known to provide a brown color, thus these results strength the possibility that the use of such dye-sources as a fiber pre-treatment associated with dyeing traditions from Iranian workshops.

The browns are still a limitant factor for the purposes of geographical attributions. The presence of compounds such as ellagic acid is often associated with dye-sources rich in tannins. This result however still presents a wide range of possibilities since a number of families of plantes are known to contain tannins. Further investigation of these dye-sources and brown historical samples are necessary to secure more specific plant attributions. Nonetheless, various compounds associated with red and yellow dye sources were identified.

These results suggest not only that brown samples have the potential to be used in the future to increase our knowledge of different dyeing traditions, but also indicates the likelihood of fiber pre-treatments as part of the dyeing practice. The establishment of the possible area of production of the carpets, relies primarily on the combined interpretation of results from yellow and red colors as these are present in the majority of the objects in this study. Consequently, the following section focuses on the results obtained from red and yellow historical carpet samples.

V.2.3. Reds and Yellows: Redifining Groups to establish origin

Fifty-four historical objects with both red and yellow fibers were used to determine regional similarities in carpet production. The remaining five carpets, namely, carpets T746, T750, T754, T756, and 27TP (see Appendix D) did not have both colors, red and yellow in their palette and so were not used. The same colors were used for the graphed points in figures V. 34 and V. 35 as were used for the corresponding clusters defined by Hierarchical Cluster Analysis (HCA) in figure V. 36. The HCA was conducted considering only the first 3 principal components resulting from PCA using Ward's method.

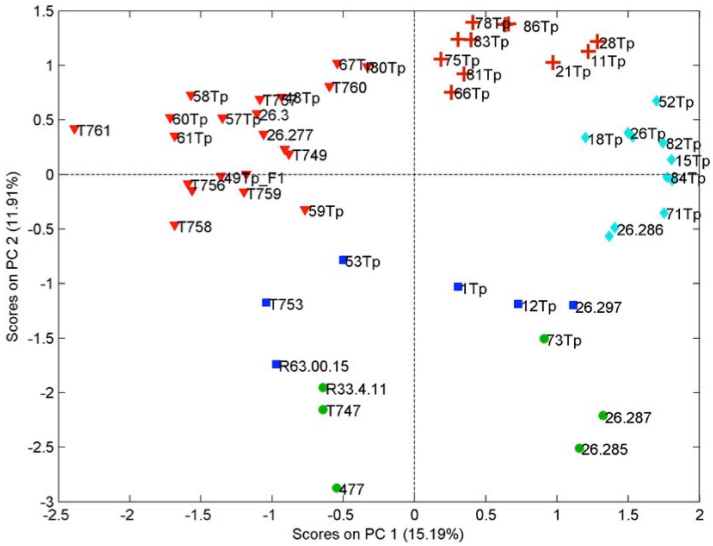


Figure V. 34: The scores plot (PC1 vs PC2) for analysis of all carpets based on the chemical information from red and yellow dyes. Graph courtesy: Jorge Sarraguça.

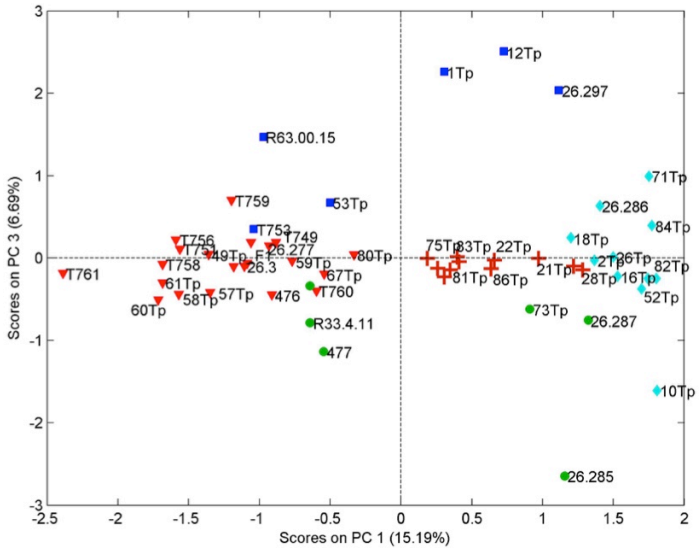


Figure V. 35: PCA scores (PC1 vs PC3) for analysis of all carpets based on the chemical information from red and yellow dyes. Graph courtesy: Jorge Sarraguça.

Figure V. 36 show the dendogram displaying the five groups from selecting a variance-weighted distance between clusters' center exceeding five. Accordingly, the combined analysis of red and yellow samples shows five different types of chemical compositions (clusters). The distribution of scores in figures V. 34 and V. 35 correspond closely to the distribution of loadings in figures V. 37 and V. 38 respectively. The compounds that contribute most significantly to the establishment of the carpet clusters are presented in table V. 6, together with the objects' inventory numbers, designs and geographical origins. The clusters are discussed individually in the following sections.

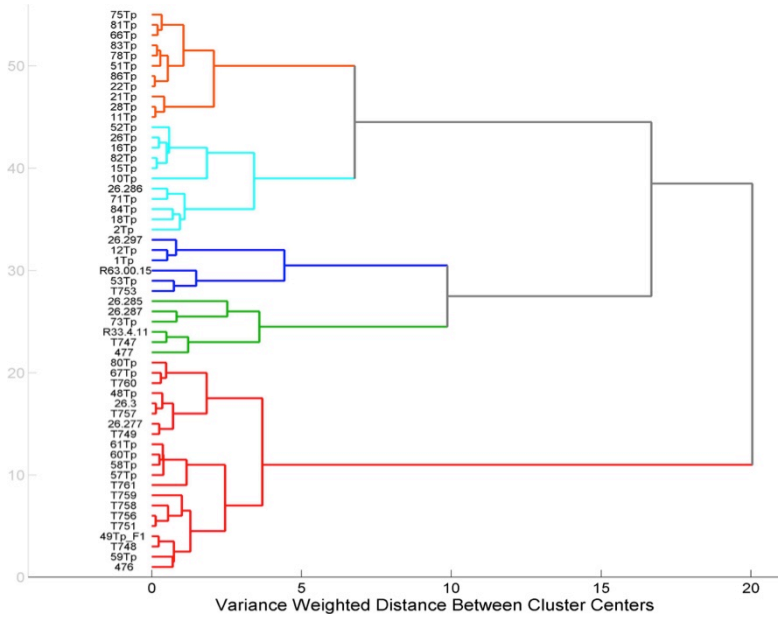


Figure V. 36: PCA scores (PC1 vs PC3) for analysis of all carpets based on the chemical information from red and yellow dyes. Graph courtesy: Jorge Sarraguça.

As discussed earlier, clusters are formed based on specific compounds, and in some cases minor compounds can influence to defining the cluster. Thus, to determine the dye-source used, one must also consider the results of the dye analysis that were determined for the individual colors to ensure that all major compounds are included. The results of the PCA analysis for individual colors were found to be mostly influence by the major compounds for each color. Hence, were used to attempt further refinement of the results from the combined PCA for red and yellow colors as it can

clarify relationship between samples that fall within the same cluster in the combined PCA analysis. It can also reveal relationships between samples of a single color that fall into two different clusters in the PCA analysis of red and yellow colors combined.

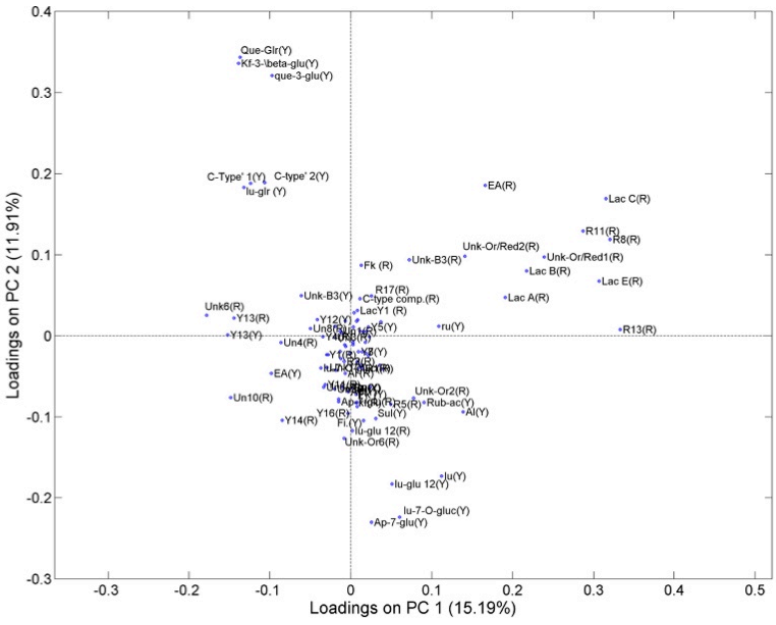
Table V. 6: Distribution of carpets obtained from PCA and HCA scores results for all red- and yellow-colored historical samples (nPC=3 dist=5) and the suggested geographical origin.

Cluster	Defining compounds*		Carpets	Design	Geographical origin
	Y	**R**	48Tp; 49Tp_F1; 57Tp; 58Tp; 59Tp; 60Tp; 61Tp; 67Tp; 80Tp; T748; T749; T751; T756; T757; T758; T759; T760; T761; 26.277; 26.300; 476.	**Border:** e, f, g, h, i, j, k, l **Field:** C2, C3, C4, D0, D1, D2, F, G	Iran?
I (Red)	Que-glr; Kf-3-beta-glu; Que-3-glu; C-type comp.; C-type comp.'1; Lu-glr;	LacY1; LacY2; Fk; C-type comp.; Lac A; Lac B; Unk-or/red 2;			
II (Light blue)	C-type comp.; ru; que-3-glu; rub-ac; fi; sul; cu; but; lu; al; que-glr; kf-3-β-glu	Lac A; B; C; E; c-type comp.; R8; R11; R13; lac Y1; lac Y2; fk; Ea; Unk-B3	1Tp; 12Tp; 53Tp; T753; 26.297; R63.00.15.	**Border:** F, India **Field:** C3	India
III (Green)	lu; lu-glu 12; lu-glu 13; lu-7-O-glu; ap-7-glu; al; rub-ac; c-type comp.; 2,6-di-OH-anthr;	Lac Y1; lac Y2; Ea; Lac A; Lac B; Fk; c-type comp.; lu-glu 12; R8; R11; R13; Lu-glu 12; Unk-Or6; Unk-or/red 2; Ap-7-glu	73Tp; T747; 26.285; 26.287; R33.4.11; 477.	**Border:** a, f, l **Field:** A, C0, C3, C4	Iran
IV (Orange)	c-type comp.; c-type comp.' 1; c-type comp.' 2; que-glr; kf-3-beta-glu; que-3-glu; lu-glr;	Lac A, B, C, E c-type comp.; Fk; Ea; Unk-Or2; Unk-Or/Red2; R11;	11Tp; 21Tp; 22Tp; 28Tp; 51Tp; 66Tp; 75Tp; 78Tp; 81Tp; 83Tp; 86Tp.	**Border:** c, d, e, f, h, k **Field:** C2, C4, D0, D1, D3, E, F	Iran?
V (Blue)	c-type comp.; fi; sul; bu; cu; but; ea; al; ap-7-glu; que-3-glu	Lac Y1; lac Y2; c-type comp.; Lac A, B, C, E Fk; Y14 Unk-Or/red 1; Unk-Or/red 2;	2Tp; 10Tp; 15Tp; 16Tp; 18Tp; 26Tp; 52Tp; 71Tp; 82Tp; 84Tp; 26.286.	**Border:** b, c, f, g **Field:** C1, C2, C3, C4, D0, D1, India	Iran ?

Cluster I (Red triangles)

Compounds associated with the yellow samples have a significant contribution to characterization of the objects in this cluster. This indicates that yellow dye-sources such as *Euphorbia* sp. (kaempferol-3-β-glucopyroside, quercetin-3-glucoside and quercetin-glucoronide) and one or more of the following *Nonea sp.* (que-3-glu and kf-3-β-glu), *Papaver* sp. (que-glr and que-3-glu) and *Prangos* sp. (que-glr) were combined in the dye bath. Likewise, sappanwood (soluble redwood component) and *Populus* sp. (luteolin-glucoronide) were also confirmed to have been use in the dye mixture (table V. 6).

By integrating all the information when considering the historical objects comprised in the Red cluster, one can see that the assortment of dye-sources used for reds is characterized by the presence of Sappanwood and one or more red insect dye-sources, i.e., *Laccifer Lacca Kerr*, *Cochineal* sp. or *Kermes* sp.[67] The presence of flavokermesic acid and lac yellows 1 and 2 (see Appendix H), together with the absence of any of the major compounds previously associated with any of the insect dyes, constrains their further association with a specific red insect.



[67] Santos et al., 2015; Serrano et al., 2015.

Figure V. 37: Loadings for PC1 and PC2 relative to PCA analysis from all red and yellow historical samples. Graph courtesy: Jorge Sarraguça.

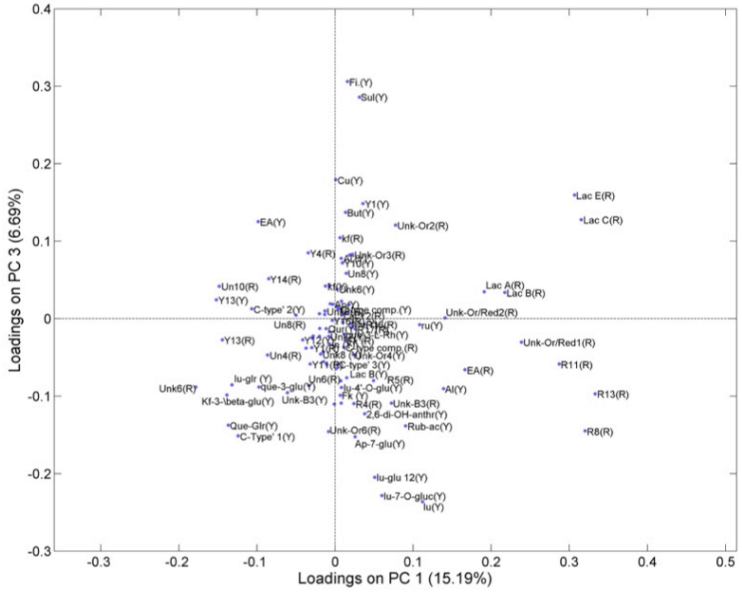


Figure V. 38: Loadings for PC1 and PC3 relative to PCA analysis from all red and yellow historical samples. Graph courtesy: Jorge Sarraguça.

The Iranian region seems to be the probable geographical location for the occurrence of the yellow-dye sources identified. Thus, one can speculate that *Kermes* sp. or *Laccifer Lacca Kerr* seem more likely due to the known popularity of their use in West and South Asia. It is also worth mentioning the absence of any carpet with Indian attribution in the Red cluster.

Cluster II (Light blue lozenges)

In contrast to the results from previous clusters, the Light blue cluster includes exclusively carpets attributed to India by their design and technique (table V. 6). Moreover, the six carpets are associated with different sites known for carpet production between the 17th and 18th centuries - specifically to manufacture in the Deccani kingdom of Golconda in the southwest region of India (carpets 12Tp and R63.00.15 in Appendix D) or at Lahore in the northwest region of India (carpet 26.286 in Appendix D).

The compounds present in yellow samples from carpets in Cluster II (table V. 6) indicate the use of young fustic, turmeric, flame of the forest, sappanwood, weld,

madder and one or more of the following dyes sources: *Nonea* sp., *Euphorbia* sp. and *Prangos* sp., major compounds associated with dye sources used in red samples are presented in table V. 6. These compounds reveal the use sappanwood, tannins, and one or more of *Laccifer Lacca Kerr*, *Cochineal* sp. or *Kermes* sp. Through the individual PCA analysis of the reds, however, it was possible to place the six carpets in two groups based on the presence of either ellagic and laccaic acids (together) or their absence.

Soluble redwood component, ellagic acid and flavokermesic acids, laccaic acids A, B, C, E, lac yellows 1 and lac yellow 2 were found to be associated with the reds from carpets 1Tp, 12Tp, R63.00.15 and 26.297 (see table V. 6). These results indicate the use of multiple dyes in combination, including sappanwood, a tannin-based dye and *Laccifer Lacca Kerr* In addition, the flavokermesic acid and lac yellows 1 and 2, suggests that one or more additional red insect dye-sources, i.e. *Cochineal* sp. or *Kermes* sp., were also used.

The flavokermesic, lac yellows 1 and 2 and soluble redwood component, were detected in the red samples from the remaining objects from this cluster, i.e. carpets 53Tp and T753. A red insect dye was used, but it is less certain which species was used. Due to the objects' geographical attribution, however*, Kermes* sp. and/or *Laccifer Lacca Kerr*, together with sappanwood, seem the most probable insect dyes.

In conclusion, these results allow us to securely associate the manufacture of carpets from the Cluster II (light blue) to India. Also, despite their association with distinct production locations in the Indian subcontinent, it can now be shown that yellow dyeing practices were less susceptible to local variation, compared to dyeing traditions for reds. Thus, research on *Laccifer Lacca Kerr* and *Kermes* sp., both red insect dye sources occurring in the Indian subcontinent appears highly promising for providing further information on Indian dyeing traditions.

Cluster III (Green circles)

The compounds present in yellow samples from the six carpets included in Cluster III (green circles) indicate the use of madder, sappanwood and one or more of the

following: weld and flax-leave daphne (see table V. 6). Both weld and flax-leave daphne are known to contain luteolin, lu-7-O-glu and apigenin-7-glucoside in their composition and are probable dye-sources for yellows in carpets belonging to this cluster. As previously mentioned one should consider that weld has been consistently found in previous studies textiles with Iranian attribution, including carpets and velvets, while flax-leave daphne is often associated with Turkish dying traditions.[68] However, all carpets in this cluster exhibit a weaving structure typically associated with Iranian production as opposed to India (see table III. 7 and section III. 2. Weaving structure).

Furthermore, the presence of *Madder* sp. compounds such as alizarin, ruberythric acid, lucidin-primveroside and 2,6-di-OH-anthraquinone in the yellows indicates that its use can be of exceptional significance for identification of yellow dyeing practices from a specific dye tradition. Only alizarin can be securely associated with a specific madder species, *Rubia tinctorum*, abundant in Iran. The use of other *Rubia* spp., such as *Rubia Cordofolia* or *Rubia Peregrina,* cannot be excluded, as additional madder compounds are present in some carpet samples. Consequently, a closer look at the PCA individual analysis of yellow and orange colors is necessary to understand what additional madder compounds occur, which can differentiate *Rubia* spp.

The carpets in this cluster have madder in the orange colors from their palette or in the orange component of their yellow colors, and occasional both. In contrary, neither of these cases was found in the Indian carpets from this study. The results from the Green cluster suggest that the inclusion of madder in the dyeing process mixed either in a yellow or orange batch, is a tradition that can be exclusively associated with Iran, confirming the absence of carpets of Indian attribution in this cluster. When looking at the results from the dye analysis of yellow and orange samples, it is significant to note that madder compounds xanthopurpurin and

[68] Böhmer, 2002; Cardon, 2007; Heitor, et al., 2007; Armindo, et al., 2008; Santos, 2010; Shibayama, et al., 2015.

purpurin are present only in carpet R33.4.11. This suggests the use of different *Rubia* species in distinct dye-batches, possible a practice from a well-resourced workshop or different dye methodology. Results from the orange samples from carpets 26.285 and 26.287 have a specific combination of compounds (ruberythric-acid and luteolin), which directs to a single production site. Alternatively, their production can also be from different workshops manufacturing closely to each in a common city or region.

Finally, one should focus on the additional compounds in the red samples in Cluster III (Table V. 6). The laccaic acids A and B are major compounds associated with the red insect dye *Kerria lacca*, while ellagic acid is frequently connected with various tannin-based dye-sources (Appendix H). The fact that objects in this cluster embody Iranian dyeing traditions has already been established; consequently one must presume that the dye-source responsible for the presence of ellagic acid in these samples can be of similar origin, since tannin-sources are locally available. One possibility is *Quercus* sp. that occurs in Iran.

The results from dye analysis of red samples can clarify if other major compounds exist and can be used to better interpret the results of objects in the cluster III. Both share flavokermesic, lac yellows 1 and 2, and soluble redwood component in their compositions. Moreover, these results indicate carpets in cluster III can be attributed to workshops in Iran, allowing the identification of two different dyeing practices. One on the presence of quercetin-3-glucoside in carpets R33.4.11, T747, and 1942.9.477 (see Appendix D), the other in the remaining carpets (73Tp, 26.287 and 26.285, see Appendix D) but of ellagic acid and laccaic acids A, B, C and E. It is important to understand these practices further in order to understand if they represent two distinct workshops from different locations, two distinct workshops from a single location, or a single workshop capable of generating different dyeing practices.

Cluster IV (Orange plus signs)

This group comprehends a total of eleven objects, all with Iranian attribution (Table III. 6). The bulk of compounds associated with both yellow and red samples are major

compounds that can be related to specific dye-sources. For yellow samples the defining compounds can be associated with sappanwood, *Euphorbia* sp., *Papaver* sp., *Nonea* sp. and *Prangos* sp. The red samples indicate the use of one or more insect dyes and *Laccifer Lacca Kerr* was most certainly used due to the presence of laccaic acids A, B, C, E, flavokermesic acid and sappanwood. While, flavokermesic acid has been reported in *Cochineal* sp. and *Kermes* sp. insects[69], the major compounds for cochineal and kermes were not detected. As a result *Laccifer Lacca Kerr* is the most likely possibility. Additionally, ellagic acid was found indicating the inclusion of a tannin-based dye. There are further minor compounds that could be useful for further investigation.

These results agree with the Iranian attribution for carpets belonging to the cluster IV. However, when looking closer at the analysis of their individual colors different dyeing practices become apparent. Based on the availability of yellow dye sources found and their limited existence in Indian carpets, such dyeing practices can be associated with Iran. However, multiple combinations of dyes were found, which points to a practice of several workshops. The differences in dyeing practices is predominantly determined by the results from yellow samples, as orange color is only in the palette for three of these objects, namely, carpets 11Tp, 21Tp and 86Tp (see Appendix D).

Thus, close observation of individual PCA analysis of yellow samples revealed two distinct dyeing practices for the Cluster IV: one for carpets 22Tp, 51Tp, 75Tp, 78Tp, 81Tp and 83Tp, characterized by sappanwood (soluble redwood component and soluble redwood components ‘1 and ‘2), *Euphorbia* sp. (kaempferol-3-β-glucopyroside, quercetin-3-glucoside and quercetin-glucoronide) and one or more of the following: *Nonea* sp. (quercetin-3-glucoside and kaempferol-3-β-glucopyroside), *Papaver* sp. (quercetin-glucoronide and quercetin-3-glucoside) and *Prangos* sp. (quercetin-glucoronide). In addition to the use of the above dye sources *Populus* sp.

[69] Serrano et al., 2015.

(luteolin-glucoronide) was used in the dye batch. The variety and quality dye-sources indicate that carpets (11Tp, 21Tp, 28Tp, 66Tp, 75Tp and 86Tp) were produced in a well-provisioned workshop.

Table V. 6: Distribution of carpets obtained from PCA and HCA scores results for all red- and yellow-colored historical samples (nPC=3 dist=5) and the suggested geographical origin.

Cluster	Defining compounds*		Carpets	Design	Geographical origin
	Y	**R**			
I (Red)	Que-glr; Kf-3-beta-glu; Que-3-glu; C-type comp.; C-type comp.'1; Lu-glr;	LacY1; LacY2; Fk; C-type comp.; Lac A; Lac B; Unk-or/red 2;	48Tp; 49Tp_F1; 57Tp; 58Tp; 59Tp; 60Tp; 61Tp; 67Tp; 80Tp; T748; T749; T751; T756; T757; T758; T759; T760; T761; 26.277; 26.300; 476.	**Border:** e, f, g, h, i, j, k, l **Field:** C2, C3, C4, D0, D1, D2, F, G	Iran
II (Light blue)	C-type comp.; ru; que-3-glu; rub-ac; fi; sul; cu; but; lu; al; que-glr; kf-3-β-glu	Lac A; B; C; E; c-type comp.; R8; R11; R13; lac Y1; lac Y2; fk; Ea; Unk-B3	1Tp; 12Tp; 53Tp; T753; 26.297; R63.00.15.	**Border:** F, India **Field:** C3	India
III (Green)	lu; lu-glu 12; lu-glu 13; lu-7-O-glu; ap-7-glu; al; rub-ac; c-type comp.; 2,6-di-OH-anthr;	Lac Y1; lac Y2; Ea; Lac A; Lac B; Fk; c-type comp.; lu-glu 12; R8; R11; R13; Lu-glu 12; Unk-Or6; Unk-or/red 2; Ap-7-glu	73Tp; T747; 26.285; 26.287; R33.4.11; 477.	**Border:** a, f, l **Field:** A, C0, C3, C4	Iran
IV (Orange)	c-type comp.; c-type comp.' 1; c-type comp.' 2; que-glr; kf-3-beta-glu; que-3-glu; lu-glr;	Lac A, B, C, E c-type comp.; Fk; Ea; Unk-Or2; Unk-Or/Red2; R11;	11Tp; 21Tp; 22Tp; 28Tp; 51Tp; 66Tp; 75Tp; 78Tp; 81Tp; 83Tp; 86Tp.	**Border:** c, d, e, f, k **Field:** C2, C4, D0, D1, D3, E, F	Iran

V (Blue)	c-type comp.; fi; sul; bu; cu; but; ea; al; ap-7-glu; que-3-glu	Lac Y1; lac Y2; c-type comp.; Lac A, B, C, E Fk; Y14 Unk-Or/red 1; Unk-Or/red 2;	2Tp; 10Tp; 15Tp; 16Tp; 18Tp; 26Tp; 52Tp; 71Tp; 82Tp; 84Tp; 26.286.	**Border:** b, c, f, g **Field:** C1, C2, C3, C4, D0, D1, India	Iran ?

* Please note other compounds were identified and are discussed inside their correspondent cluster. Only the most significant for defining clusters are presented in this table.

Cluster V (Blue squares)

Lastly, all eleven carpets found in the Cluster V (blue squares) attested the use of sappanwood (soluble redwood component) in both red and yellow samples (Table III. 6). Weld or flax-leaved daphne (apigenin-7-glucoside), tannins (ellagic acid), young fustic (fisetin and sulfuretin), turmeric (curcumin), flame of the forest (butin and butein) and madder (alizarin) are significant dyes sources for yellows samples in objects from this cluster. Moreover, the presence of quercetin-3-glucoside, indicates that one of the following yellow dyes sources was used: *Nonea* sp., *Euphorbia* sp. and *Papaver* sp.

The results indicate that several dye-sources were used together. However, their combination diverges from object to object. In carpet 71Tp, for instance, sappanwood is found with young fustic, turmeric and flame of the forest, while in carpet 26.286 sappanwood was detected with one of the following yellow dyes sources was used: *Nonea* sp., *Euphorbia* sp. and *Papaver* sp. together in samples. Moreover, through the individual PCA analysis of yellow samples three different procedures for yellow dyeing become obvious from carpets in Cluster V. The first, is found in carpets 2Tp, 15Tp, 16Tp, 18Tp, 52Tp, 82Tp and 84Tp (see Appendix D), containing sappanwood (soluble redwood component), weld (luteolin and apigenin), madder (ruberytric acid), *Euphorbia* sp. (kaempferol-3-β-glucopyroside, quercetin-glucoronide) and one or more of the following: *Nonea* sp. (quercetin-3-glucoside and kaempferol-3-β-glucopyroside), *Papaver* sp. (quercetin-3-glucoside and quercetin-3-glucoside) and *Prangos* sp. (quercetin-glucoronide).

The second yellow dyeing tradition from carpets 10Tp, 26Tp and 26.286 (see Appendix D) contains a mixture of sappanwood (soluble redwood component, soluble redwood component' 1 and '2), tannin-based dye (ellagic acid), *Populus* sp. (luteolin-glucoronide), weld (quercitrin and apigenin-7-glucoside), *Euphorbia* sp. and one or more of the following: *Nonea* sp. (kaempferol-3-β-glucopyroside and quercetin-3-glucoside) and one or more of the following: *Nonea* sp., *Papaver* sp. and *Prangos* sp.(que-glr). The third and last yellow dyeing practice is found in a single object, carpet 71Tp (see Appendix D) and includes flame of forest (butin and butein), young fustic (fisetin and sulfuretin) and turmeric (curcumin), all recognized exclusively as occurring in India. Noteworthy is the fact that this carpet is attributed to India on the basis of technical features. Additionally, object 26.286 is associated with India and included in this cluster.

The yellow dye-sources are the main difference between these two Indian objects. Both share the occurrence of *Laccifer Lacca Kerr* (laccaic acid A, B, C and E), *Kermes* sp. and *Cochineal* sp. (flavokermesic acid), tannin-based dye and sappanwood in their red compounds. Additionally, carminic acid, a major compound from *Cochineal* sp., was detected with *Kerria* in red samples from silk carpet 26.286, a silk carpet.

This result shows that *Cochineal* sp. occurs in Indian dyeing practices, in association with silk fibers. Moreover, the absence of madder compounds from yellow dyes in Indian carpets reinforces the notion that the use of madder in yellows can solely be associated with Iranian dyeing traditions.

Flavokermesic acid (a compound that can be found in cochineal, *Kerria* or *Kermes*) without traces of any major compounds for *Cochineal* sp. was found in the remaining Iranian and Indian wool pile carpets integrated in this study. This suggests an association with a specific *Kerria* or *Kermes* species in these carpets. Both red insect dyes are known to occur in Southeast Asia and known to be use in Iranian dyeing traditions.[70]

[70] Santos, 2010; Shibayama, et al., 2015.

Yet, the combined presence of sappanwood, tannin-based dye, *Populus* sp., weld, *Euphorbia* sp. and/or *Nonea* sp. also occur in dyes from Indian and 'Indo-Persian' carpets. Whether this similarity in dyeing-practices can be associated exclusively with silk dyeing or a particular workshop practice in the Indian subcontinent during 16th and 17th centuries remains to be fully understood, thus requiring the analysis of additional objects.

V. 4. Final Interpretations

The different combinations of red and yellow dye-sources used together in the carpets in this study support the existence of multiple dyeing practices. This result permits differentiation of carpet production geographically, namely to Iran or India, based on the analysis of their dyes. Five clusters of objects were determined by means of combined PCA analysis of the chromatographic results from 54 historical objects. Furthermore, the results allow discerning the level of sophistication of carpet manufacture based on the assortment of dye sources.

The chromatographic results obtained provide a window into 'Early Safavid', 'Indo-Persian' and Indian dyeing traditions during 16th and 17th centuries. This study adds to the group of known dye sources previously documented to compose the color palette of carpets attributed to Iran. In addition to *Kerria*, weld, madder and tannins, reported to occur in red, pink, yellow, orange and brown colors, other dye sources are now known to be used in Iranian carpet production during the Safavid period from 16th to 17th centuries.

Dyes identified in red and pink colors indicate the use of red insect dyes for carpets attributed to 'Early Safavid' and 'Indo-Persian' types (table III. 7): *Laccifer Lacca Kerr* alone or in combination with *Kermes* sp., as well as tannins and sappanwood. No red insect dyes were found in the orange samples from 'Early Safavid' and 'Indo-Persian' carpets. Instead, oranges samples have a mixture of madder (*Rubia* sp.) and a yellow-dye exclusively. The results indicate that the inclusion of madder in yellow or orange historical samples can be exclusively

associated with 'Early Safavid' and 'Indo-Persian' dyeing practices. No madder compounds were found in Indian carpets. Together these results are consistent with previous studies on Iranian carpets in Portuguese collections, reinforcing the idea that this color combination is characteristic of a classical Iranian palette.[71]

By contrast, the number of dye sources recognized in yellow colors is significantly higher than what has been reported to date for Safavid carpets. For the first time, results from yellow samples suggest in addition to weld, the use of the following dyes: *Euphorbia* sp., *Papaver* sp., *Prangos* sp., *Nonea* sp., Anacardiaceae, *Populus* sp. and flax-leaved daphne.

Additionally, sappanwood, madder and tannins were identified in a large number of these yellow samples, which indicates they were present in the dye-bath, presumably as an intentional addition by the master-dyers. With the exception of madder, found solely in deeper yellow hues, the intended use of sappanwood and tannins in yellow dyeing is unclear. However, one can speculate that they were used as a fiber pre-treatment or as a mordant.

Similarly, the use of red insect dyes were found in reds and pinks found in Indian wool pile carpets (table V. 6): Laccifer Lacca Kerr alone or in combination with *Kermes* sp., as well as sappanwood. The use of tannins in reds does not appear as consistent as in 'Early Safavid' and 'Indo-Persian' carpets.

It does however for yellows together with young fustic, turmeric and flame of the forest. Furthermore, such combination in yellows appears to be a common dyeing method for wool pile carpets across the different regions of the Indian subcontinent, including Golconda or Lahore. The exception is the silk pile carpet (26.286) in which cochineal and *Kerria* were found together in the reds. Likewise, the combination of sappanwood, *Euphorbia* sp., *Papaver* sp. and *Nonea* sp. are found together uniquely in this object. The use of expensive red insect and yellow plant

[71] Santos, 2010.

dyes in the silk fibers suggests a distinct production location, most likely a well-resourced workshop in close proximity with the Mughal court.[72]

Studies to identify natural dyes in historical textiles have come a long way, but various obstacles for associating dye compounds with specific dye-sources remain, as seen also other in recent studies.[73] The colorant composition is directly related to the type of fiber, dye, and the different dyeing parameters applied, which together cause different reactions during the dyeing process resulting in different dye compositions.

As a result, it is not possible to further narrow the identification of dyeing procedures, nor to associate them with master-dyers from different workshops. Furthermore, comparison between experimentally-dyed, aged samples and with historical ones, together with further identification of *Kerria* and *Kermes* insect, as well as madder and the various yellow plant dyes found would be necessary to comprehend and ascertain the occurrence of the various minor and unknown compounds detected.

Nonetheless, the results significantly increase our knowledge of the intricacy of Iranian and Indian dyeing practices during the classical period, while contributing to an understanding of the extent of their variations. It is evident that the usage of color can be more than an aesthetic matter accompanying carpet design; it is a statement of the sophistication and complexity of Islamic carpet production in the 16th and 17th centuries. In the next chapter – *Chapter V. Dating* – we analyze this matter further by looking into the development of carpet designs.

[72] This is reinforced by recent studies: Serrano, 2016, pp. 116-118.

[73] Serrano, 2015, p. 125; Gürses, et al., 2016.

CHAPTER VI
DATING

On the basis of visual sources it is possible to closely establish when a carpet first arrived in Europe and, by extrapolation, approximately when it was made in Asia. Indeed, by identifying the earliest example for the depicted carpet types we can provide a *terminus ante quem*[1] date to a certain design. The methodology of establishing a relative chronology by looking at their depictions in European paintings as has been well demonstrated by John Mill's work,[2] over the past few decades cataloguing carpets in paintings from European collections.

For carpets attributed to the 16th and 17th centuries an important reference is the work of Onno Ydema, who developed an extensive inventory of carpets depicted in Netherlandish paintings, attempting to date different types of carpets using depictions of fields and borders.[3] In addition, Hallett collected a list of paintings in Portugal complementing his findings.[4]

This chapter looks at Onno Ydema's methodology, then discusses some of its limits and attempts to review it on the basis of the designs examined from the real objects in the previous chapter as well as the Dutch and Portuguese paintings surveyed in this study. Finally, it associates the earliest dates collected from the paintings with the major border groups (figures V. 1 and V. 2) described in the previous chapter.

VI. 1. Limitations in Ydema's Methodology

Ydema's study entitled *Carpets and Their Datings in Netherlandish Paintings 1540-1700* looks at 960 paintings. After understing the strong appeal that richly designed

[1] "Interpreting the Evidence", Smithsonian Education, accessed May 25, 2016, http://www.smithsonianeducation.org/educators/lesson_plans/decoding_the_past/interpreting.html.
[2] Mills, 1975, 1978, 1983, 1988, pp. 42-44.
[3] Ydema, 1991.
[4] Hallett, 2007d.

Islamic weavings with curious ornaments had to Dutch painters, Ydema attempts to date the depicted carpets, while developing a database system using their motifs in order to categorize them in relation to origin.

His primary focus on Netherlandish pictorial sources from the 16th and 17th centuries is explained by the fact that in 17th century "the interest of Italian painters in representing Oriental carpets had strongly declined".[5] In the Netherlands, at the end of the 16th century, and especially during the 17th century, carpets were predominantly depicted in still-lives, portraits, genre and history paintings.

Figure VI. 1: Lourenco de Salzedo, *Queen Catarina* with Saint Catherine. 1564, Lisbon, Museu Nacional de Arte Antiga. Published by Hallett, 2010.

Ydema explains that Persian carpets forming part of the regular Asian commerce were traded to Western Europe at the end of the 16th century, with the Portuguese being the first to start a flourishing trade with India and Persia, countries which could now be reached directly via the new trade route around the Cape of Good Hope.[6] In fact, Hallett's work, shows that carpets depicted earlier in Portuguese royal portraits the mid 16th century (Figure VI. 1).

Gradually, Iranian and Indian carpets began to be represented in Dutch painting, with Anatolian, Persian and Indian carpets were the most frequently represented. Ydema designed a codebook for processing information as standard data dictionary when developing a database of paintings.[7] Descriptions of all carpet design systems visible in the paintings were gathered and divided according to three criteria:

[5] Ydema, 1991, p. 10
[6] Ydema, 1991, p. 10.
[7] "Since the beginning of the project it was quite clear that the storage or retrieval of the information could not be done conveniently by hand" Ydema, 1991, p. 16.

the patterns of the field, the major border, and the minor borders. Moreover, the distinction between *Anatolian and Chessboard*, *Persian*, *Indian*, *Egyptian* and *'Namenlose Gattung'* carpet design is associated with the letters a, b, c, d and e, respectively. However, for the aim of this analysis, only chapters IV and V, corresponding to *Persian* (design b) and *Indian Carpets* (design c), respectively, are considered.

Ydema's classification system is presented at the end of his publication and is composed of three sets of alphanumeric characters. In the first indicated by a letter, refers to the group of carpet designs where field patterns are associated to the assumed provenance of the object. The second indicated by a letter and a number refers to the major border. Finally, the third referring to minor border patterns uses the letter g (guard) followed by a number, i.e., *g6 - zigzag* and *g9 - 'barber-pole'* ornaments. In case the depicting carpet offers the entire assembly of these elements[8], an additional *i* or *o* is added before the *g* to denote to inner or outer guard border, respectively.

Furthermore, to discern subcategories within carpet groups a second letter was added, i.e., *bi – floral and cloudband pattern* refers to the subgroup of Persian design, the so-called 'Indo-Persian' carpets, while *bv* for carpets from North-West Persia. Border patterns associated with Persian carpets are characterized by the letter *b* and a number is added to discern different border types, i.e., *b6 - cartouche design*. If a pattern cannot be identified, it is not given a code and a dot is added between design elements to avoid communication problems in the database.[9] This clarification is vital to understand not only how the database is constructed but also how to use it.

One of the problems with Onno Ydema's work is the lack of a complete description concerning the features he uses to establish each group. Furthermore, there is little information about his criteria to associate depicted carpets with a specific

[8] The results of the research depend entirely upon the degree of care with which each painter 'portrayed' his models. It will be clear from the results of this study that the general Dutch and Flemish painters took great effort to represent the costly Oriental weavings in great detail with particular regard for accuracy of representation.

[9] Otherwise if the user would recall a list of all carpets in the inventory, he would get the aii. and a aiii carpets as well, not to mention all records with words like 'available', or names like 'Bailly'.

origin. He pinpoints probable regions in Iran based on references given by "scholars", without providing any reference sources.[10] For Persian carpets the *Floral and Cloudband* type is solely described as a group of carpets characterized by *"*a symmetrical pattern of coiling stems, numerous large and smaller flowers and 'tchi', or cloudband ornaments of Chinese origin".*[11]* This generic description turns out to be incomplete, as no explanation is given to where these elements appear in the carpets, i.e. field, borders, etc.

Various motifs were considered to form multiple subgroups within the *b-Persian carpets*, thus making the incompleteness of the description even more evident. No information is provided as to which design elements (motifs) Ydema's method uses to differentiate the carpet groups. Nonetheless, his method establishes five different subgroups of field patterns, namely: bi. - *Floral and Cloudband design*; bii. - *Floral designs including representations of animals*; biii. - *Floral design composed of stiff stems connecting opposed palmettes or lotus flowers*; biv. - *Other floral carpet designs except North-West Persian designs* and bv. **-** N*orth-West Persian designs*. The *Floral and Cloudband design* (bi.) is the most generic designation for the field design, and Ydema method includes other subgroups under a similar designation. While this justifies its wide chronology including paintings dating from 1598 to 1700, it stresses the need of a detailed and systematic explanation about his decision-making for a suitable methodology for dating carpets using paintings is lacking. This information is necessary to allow the comparison of his results with existent carpets from collections in Portugal, or elsewhere in the world.

Although these pictorical sources offer *termini ante quem*, choices had to be made regarding what representations to include. Ydema noted that the trustworthiness of the conclusions depends on the reliability of the dating of the paintings.[12] Therefore, copies of paintings were excluded from his inventory, even

[10] "the East-Persian province of Khorasan, with Herat as its capital, has been mentioned by many 17th-century travellers as the most important centre for the manufacture of such fine-quality carpets with a woollen pile, although scholars are still divided between Central Persia, Khorasan and India as possible places of their manufacture" Ydema, 1991, pg. 15.
[11] Ydema, 1991, p. 11.
[12] Ydema, 1991, p. 15.

when such copies were made in the 16th and 17th centuries.[13] Fortunately a firm consensus exists among art historians in dating the works of the best-known artists; other sources for a chronological ordering of paintings used in his work are the art historical dating given in other publications such as catalogues of museum collections and exhibitions, or in individual scholarly articles.[14]

In his work Onno Ydema explains that, as the available photographic material are mainly in black-and-white, one of the problems of using paintings to study carpets is the often impossible description of the carpets' colour scheme. Moreover, with the exception of some examples presented by Mills,[15] technical characteristics – weaving structure – or the comprehensiveness of their field and border design depictions are often difficult to determine when looking at paintings. Nevertheless, approximately 300 paintings depict what he named as Persian and Indian groups, providing a significant number of pictorial examples to the study and understanding of the so-called 'Indo-Persian' carpet design and its possible evolution.

VI. 2. Dating the Carpet type

While Ydema's work provides *terminus ante* and *post quem* dates for the 'Indo-Persian' group, it does not attempt to establish dates for different types and their evolution. Through a comprehensive study of his work on carpets and their dating in Netherlandish paintings it becomes evident that information provided by paintings to trace chronological evolution of design can be limited for a number of reasons. Very rarely for example, do paintings give us a clear idea of both the field and border designs. Moreover, carpet depictions could be vulnerable to the creative process of the painter or to personal requests and taste of the client, thus it is essential to relate the depicted carpets with real objects. Therefore, we use carpets from this study to support or enrich information on the dates provided by paintings (Figures VI. 2 and VI. 3).

[13] Exception was made for 16th- or 17th-century copies displaying a carpet that differs from the one represented in the original painting.
[14] Ydema, 1991, p. 15.
[15] Mills, 1978.

Figure VI. 2: *Carpet with pattern of scrolling vines.* Unknown location, former CGA, Inv. No: 26.297.

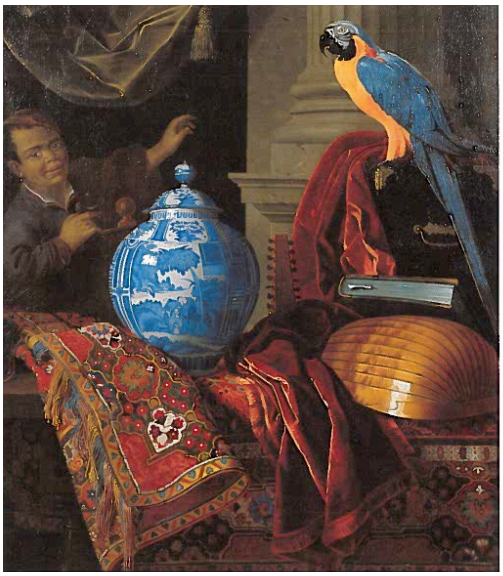


Figure VI. 3: Cornelis de Man (1621-1706), *Still-life with a Servant and a Parrot*. 1667 or later, Frankfurt, Historiches Museum. Published by Ydema, 1991.

The results from the earliest dates gathered by Ydema seem to support the possibility that developments in 17th-century carpet production occurred in three stages (Table VI. 1).

Table VI. 1: Dates associated with borders and their occurrence with various fields.

			A	B	C0	C1	C2	C3	C4	D0	D1	D2	D3	E	F
late 17th century	1680-85	j							●						
mid 17th century	1660-65	h						●	●		●				
	1653	g								●	●				
	c.1650	c					●								
	1659	b									●				
Late 16th to early 17th	1628	l	●												
	1598	f	●		●	●	●	●	●	●			●		
	c.1619	a	●		●										
-	?	k													●
	?	i									●	●			
	?	e								●			●		
	?	d					●							●	

This sequence is also reinforced by Portuguese paintings, although their absolute dates are a decade or so later. The enthusiasm of the Dutch bourgeoisie to

have themselves portrayed with fashionable objects from overseas, such as the *Vine scroll with Central Void and Clouds* (Figure VI. 4) was not shared by Portuguese patrons who generally preferred to commission religious works of art (Figure VI. 5).

Figure VI. 4: Unknown Flemish artist, *Portrait of Jean Charles de la Faille, Lord of Rymenam, aged 30*, 1598. Brussels, Koninklijk Museum voor Schone Kunsten.

Figure VI. 5: Domingos da Cunha, *Mass of Saint Ignatius of Loyola*, c. 1632. Lisbon, Museu de São Roque. Published by Hallett, 2007.

The first stage, taking place at the end of the 16th century and continuing on into the early 17th century, appears to be limited to borders a, f (in its earliest manifestation) and l (see Table VI. 2 and Appendix K). These results are in line with previous research devoted to Timurid and early Safavid carpets by scholars, such as Klose and Denny.[16]

[16] Klose, 1994; Klose, 2010; Denny, 2010; Denny, 2011.

Table VI. 2: Border designs associated with the first stage of carpet production.

Border designs	Example of border design	*Terminus ante quem* date	Stage of carpet production
l		1628	Late 16th to early 17th century
f		1598	
a		c. 1619	

A second stage followed with the appearance of the single vine meander with lotus palmette and large buds (border c) before the middle of the century, and then with a diversity of border designs, which included the arabesque vine (border b) and compositions with sickle leaves (see Table VI. 3 and Appendix K).

Table V. 3: Border designs associated with the second stage of carpet production.

Border designs	Example of border design	*Terminus ante quem* date	Stage of carpet production
h		1660-65	Mid 17th century
g		1653	
c		c. 1650	
b		1659	

The first sickle leaf design appears by 1653 (border g – *Lotus palmettes alternating with pairs of curved sickle leaves clasping rosette*) and occurs in the 1653 painting attributed to Gerrit Dou (1613–1675), *The Physician* (Figure VI. 6), and then is

elaborated in border h (*Pair of curved sickle leaves clasping lotus palmettes*) by 1660-65 (Figure VI. 7).

Figure VI. 6: The Physician. Gerrit Dou (1613–1675). Austria, Vienna 1653. Vienna, Kunsthistorisches Museum.

Figure VI. 7: Borders designs associated with the third stage of carpet production

Finally, by 1680-85, towards the end of the century, an entirely new border appears, namely border j – *single vine meander with rosette and bud*, which appears to reflect a third stage in the development of carpet design (see Table VI. 4 and Appendix K).

Table VI. 4: Borders designs associated with the third stage of carpet production.

Border designs	Example of border design	*Terminus ante quem* date	Stage of carpet production
j		1680-85	Late 17th century

Borders d, e, i and k don't have dates, yet if we compare the patterns observed above with the fields, it is possible to propose some dates (see Table VI. 5). Firstly, it is important that early borders a, f, and l occur together with fields A, B and C0, all of which were considered from the design analysis presented in Chapter IV to be early types, thus confirming the relative dates.

Secondly, border f is the longest running design seen in paintings, over the course of a century, from 1598 until 1698; this ongoing existence can be verified by its association with a wide range of field variations (all of C as well as D0 and D3). Hence, border f can be used to follow the increasing creativity of field designs. Furthermore, more detailed and sophisticated versions of border f are recognized with early fields A and C0, C1, whereas it appears in a plainer and stylized form with later fields C3, C4 and D0. Border j, which is late and developed by circa 1680-85,[17] is found in association with C4, the latest variation of C, rather than with any of the earlier ones. Thus, reinforcing that we are looking at a chronological evolution with field C0 coming first, followed by C2 which is associated with border a (c. 1619) and then finally by C4.

Thirdly, two borders, *c* and *d*, are seen with field C2. Border c – single vine meander with lotus palmette and large buds occurs by 1650,[18] and thus suggesting that border d, which lacks an *terminus ante quem* date, could also be a possibly development from the 17th century or so, in which the lotus palmettes was applied to new border compositions. Fourthly, border designs g, h and i, with sickle leaves, are displayed in paintings from 1650s and 1660, and associated with a wide range of fields:

[17] See Appendix K: C. the Man*, Discussion in a Laboratory* (90 x 112 cm), 1680-85, Warschaw, National Museum. Ydema, 1991, Cat n. 629)

[18] See Appendix K: S. Luttichys, *Still-life* (57.5 x 45cm), c. 1650, Berlim, Germany. Ydema, 1991, Cat n. 508)

namely, C3, C4, DO, D1 and D2. This would seem to imply considerable design experimentation during this period.

Table VI. 5: Borders designs possibly associated with the second and third stages of carpet production.

Border designs	Example of border design	*Terminus ante quem* date	Stage of carpet production
k		?	From mid 17th century
i			
e			
d			Around mid 17th century

It is noteworthy in this regard that from these three borders (g, h and i), g – *lotus palmettes alternating with pairs of curved sickle leaves clasping rosettes* – is the first example to make its appearance in Netherlandish paintings (by 1653)[19] and is also found in real objects with the first two variations of fields with sickle-leaves, namely DO and D1. The latter (field D1) is also found in association with two different sickle-leaf borders h and i. A third field (D2) is also found with border i. This coexisting correlation of sickles leaves in borders and fields seems to point towards a brand-new development in design. Border h also appears in two fields without sickle leaves, namely C3 and C4 suggesting these as possible overlapping developments in design.

Finally, E and F fields display a tile pattern design. The latter found exclusively in objects with border k and with no *terminus ante quem* date determined, while the field E found in a single object shares border d another object with field C2. This indicates that border d was used with earlier classical field design (before 1650) and

[19] See Appendix K: Gerrit Dou. *The Physician*, 1653. Kunsthistorisches Museum, Vienna, Austria. Ydema, 1991, Cat n. 384a)

was maintained either during a later (after 1650) or localized production where repeated patterns designs were popular.

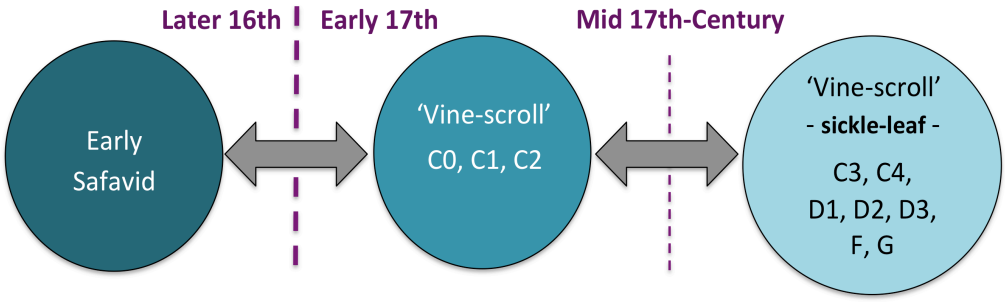


Figure VI. 8: Field design evolution – from a small to wider variety of designs.

Taken as a whole, the combination of designs with relative and *terminus ante quem* dates indicates the rise of a small number of initial designs mainly with palmettes, cloud bands and chenar leaves at the end of the 16th and beginning of 17th centuries, which was followed in the middle of the 17th century by a growth in the variety of designs and the emergence of an entirely new group, namely with sickle leaves in the field and border (Figure VI. 8).

This evolution from a small number of designs to a much wider variety raises a number of questions: Were all these developments the products of a single manufacturing center? Or do they reflect the rise of the type in one center and its rapid spread to other centers, where further developments took place? And if there was dissemination of production, did this occur in the scale of a town or something larger, like a region or even multiple regions? Was consumption playing any role in this dissemination? How? Where this new designs developed to fulfil a specific demand?

These questions manifest how date and origin are problems that are intrinsically related. Indeed, this relationship stresses the importance of addressing these problems in the study of historical carpets. Above all, carpets are the resulting product of a complex chain of operations, some are fixed for long periods while others can change suddenly or evolve with great speed. Thus, attempting to solve problems of origin it is not complete without considering the broader context of their production, requiring an interdisciplinary approach.

CHAPTER VII

PRODUCTION AND CONSUMPTION

The so-called 'Indo-Persian' carpet type results from the combination of certain materials, techniques and designs during the manufacture process. In this dissertation information about these three features is combined to determine the origin and date of the 'Indo-Persian' carpets and understand whether they were products intended for export. The evolution of the industry, discussed in previous chapters, reveals a series of transformations during the 16th and 17th centuries, which appear to reflect a response by carpet workshops to the increasing appreciation of various consumers, particularly in 17th-century Europe.

On the basis of fibre, technique, design, color and dye analysis this chapter presents a system of carpet classification for the various carpet types currently under the 'Indo-Persian' designation. Moreover, the relative chronology established in the Chapter VI is used to further develop this system. By bringing together the diverse results acquired with this interdisciplinary method, it is possible to better establish their origin and date, while also assessing aspects of their production and consumption.

This chapter begins by considering questions concerning their production on the basis of the material, technical and design analyses from previous chapters. The complete summary of these results is organized according to the carpets groups established by statistical methods using red and yellow samples and is presented in Appendix L. Each group reflects differences in the use of fibers, techniques, color palette, dye-sources, and border and field designs. These characteristics are discussed and an origin proposed. Finally, the chapter looks at their consumption by exploring the role of changing tastes in transforming the Iranian carpet industry. It examines how differences in carpet function and the popularity of particular designs had an impact in the choice of materials and dimensions of these objects**.**

VII. 1. Production

As demonstrated in Chapter V, different combinations of red and yellow dye-sources used together for carpets in this study support the existence of multiple dyeing practices. The majority of objects in this study (54 carpets) include red and yellow colors, which can be use to establish Iranian or Indian origin. To further narrow their attribution within these vast geographical areas it is require to combine the information from fiber, technique, and designs analysis. The five groups determined through PCA analysis, of their combined chromatographic results (see Chapter V, section V. 2. 2. 3), is used as the basis for looking at relationships between objects that could indicate different manufacturing practices and possible scale of workshops and their settings.

The variety of choice of fibers, techniques, color and dye sources exhibited by objects in each group discloses the level of sophistication of carpet manufacture, offering a window onto Iranian and Indian manufacturing traditions and their development during 16th and 17th centuries. Detailed information about each group can be found in Appendix L. The results from the remaining five objects, which do not include either red or yellow colors, namely, carpets T746, T750, T754, T756, and 27Tp, are associated with a particular production group based on the comparison of all their other characteristics.

The diagram in Figure VII. 1 presents all the carpet groups and two major moments of carpet production, which will be described in due course. The discussion here starts by addressing the major differences between Indian and Iranian carpet manufacturing practices, namely groups II and III. It then focuses on the developments of Early Safavid production to understand later developments by looking at Group V, “New Markets”, and finally at Groups I and IV.

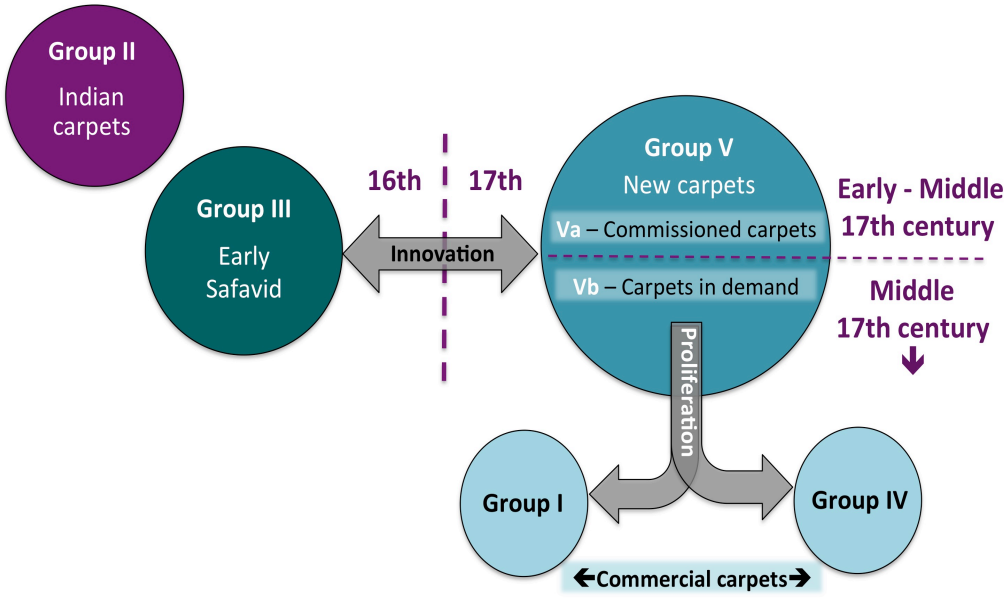


Figure VII. 1: Diagram presenting the five carpet groups and two major moments of carpet production.

Indian carpet production is recognized from Group II (Figure VII. 1), encompassing six objects, which includes results from carpets with Indian attributions and dated from the 17th to 18th centuries (see Appendix D and L). The Indian dyeing practices portrayed by objects in this cluster indicate that reds include *Kerria* sp., kermes, tannins and sappanwood, while yellows are consistently achieved by using young fustic, turmeric and flame of the forest – a mixture of local dye sources (Appendix L). Moreover, the color palette from Indian carpets does not include the use of orange, further reinforcing the differences between the Indian palette and Early Safavid dyeing practices (Figure VII. 2).

For this study, 17th-century carpets with Indian attribution were deliberately selected for their designs, which contrasted with the classical 'Indo-Persian' type.[1] From the total seven Indian carpets, five grouped together, including the two *Safs* which have long been attributed to production in the Deccan region (carpet 12Tp and R63.00.15, Appendix D). Thus, in addition to reinforcing an Indian attribution for the five objects, these results also indicate a close relationship between the two *Safs* and that they were probably produced in Deccan, possible by a single workshop.

[1] Although these Indian carpets are excluded from the design analysis, this does not jeopardize the methodology used in this thesis, as the objective is to compare their scientific results for purposes of material classification.

Similarities between technical features and the use of sappanwood in the yellows, however, suggest two distinct workshop traditions: one responsible for carpets 53Tp and 26.297, and another for R63.00.14 and 12Tp. The first, showing the North Indian design of lattice network with flowers on a red ground (53Tp), showing a *ton-sur-ton*[2] coloring, surrounded by a cartouche border (26.297), while the latter two are both fragments from a multiple-niched prayer carpet (*Safs*), often associated with Deccan.[3] Finally, carpet 1Tp could represent a third tradition in which mirror image field design with large sickle leaves and other flower elements displayed with a border of intertwined flowers (see Appendix D).

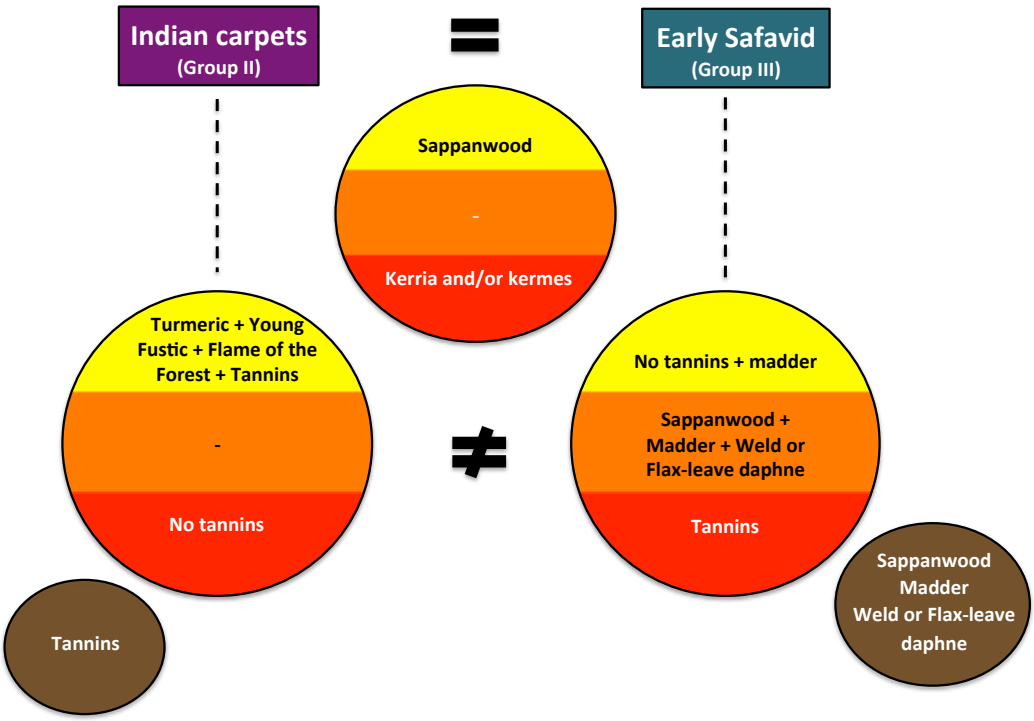


Figure VII. 2: Diagram presenting similarities and differences between dye practices between Groups II and III.

It is noteworthy that the only carpet of the 'Vine scroll with Central Void and Clouds' type that groups with these five Indian carpets, based on the same dyes, is carpet T753. This objects displays border f, which the longest running design seen in paintings, over the course of a century, from 1598 until 1698 (see Chapter VI). Together, with elements of the design, such as the *ton-sur-ton* effect in the light

[2] "(...) *ton-sur-ton* colour combination, when two or more shades of the same colour are juxtaposed without the intervention of another colour". Cohen, 2010, p. 131.
[3] Beattie, Ellis, Erdmann, 1982, pp. 220-238.

green inner minor border and green major border, and the pink horseshoe-shaped clouds against the red field, its presence in Group II suggests that carpet T753 could be an example of 'Vine scroll with Central Void and Clouds' produced in India.

Carpets in Group III represent early Safavid production. The manufacture of the six carpets is consistent and includes the use of silk warps, high knot density, sophisticated and dense designs, and rich color palette. Their technique, high quality materials, palette and the relative chronology of their designs suggest production from well-resourced and organized workshops, likely working closely with (or observing) Safavid court-sponsored workshops between the late 16th and early 17th centuries.

The red historical samples from the six carpets included in Group III indicate the use of tannins, *Kerria* and possibly kermes, while yellows can be characterized by the presence of madder, sappanwood, and one or more of the following: weld and flax-leave daphne (Appendix L). As previously mentioned in Chapter V, weld has been consistently found in previous studies of textiles with an Iranian attribution, including carpets and velvets[4], while flax-leave daphne is often associated with Turkish dying traditions.[5] A possible Turkish origin for this group however, is refuted by the presence of madder, which has been shown to be a characteristic exclusively of oranges in Safavid carpets but not in contemporary Turkish carpets, where madder is typically used for the reds.[6]

The presence of *Rubia* sp. compounds such as alizarin, ruberythric acid, lucidin-primveroside and 2,6-di-OH-anthraquinone in the yellows indicates that its use can be of exceptional significance for identifying regional dyeing practices. Only alizarin, however, can be securely associated with a specific madder species: *Rubia tinctorum*, abundant in Iran. Given the presence of the other madder compounds mentioned above, the use of other *Rubia* sp. dye-sources, such as *Rubia Cordofolia* or *Rubia Peregrina,* is also possible and cannot be excluded.

[4] Heitor et al, 2007; Armindo et al, 2008; Santos, 2010; Shibayama et al, 2015.
[5] Böhmer, 2002; Cardon, 2007.
[6] Santos, 2010; Böhmer, 2002.

The carpets in the Early Safavid group reveal the presence of madder in two colors: oranges or in the orange component of the yellows. Dye analysis supports the high quality of carpets T747 and 1942.9.447, not only due to the use of expensive red insect dyes (*Kerria* and/or kermes) but also through the presence of complex yellows. Two distinct combinations of yellow plant dye sources are present (see Appendix L). This can be observed in the red samples from both of these objects, which combine one or more of the following yellow dye-sources: Euphorbia L., *Nonea* sp. and *Papaver* sp. By contrast the yellow samples revealed a different combination of yellow-dyes sources, namely, weld, flax-leave daphne and madder.

According with the conditions of the dye bath, madder is known to provide an orange hue to wool fibers and therefore, was probably added to provide a warm hue to the yellows in these carpets. However, the variable use of madder and sappanwood in the oranges indicate differences in dyeing procedures between the two objects. In 1942.9.477 madder is detected in yellow, orange and brown samples, and sappanwood is present in all colors, whereas in T747 madder is only found in yellows and oranges (absent in browns), and sappanwood is detected solely in oranges and browns.

This methodology was also useful for determining the relationship of carpet fragments that lacked complete design information with intact objects. For example, fragment R33.4.11 with animals in the field clustered with Group III (see appendix D), together with the only other object depicting animals, carpet 1942.9.477. However, when comparing the two objects, the former (R33.4.11) is revealed to be an inferior grade of carpet owing to the presence of Z3S cotton threads instead of silk and its moderate execution of the design. Moreover, a close relationship between the choice of dyes and field design is apparent in carpets T747 and 26.287, which displaying Field C0 (see Appendices D and L). Their border designs are different (f and a, respectively), but both are early designs types seen in 16th and early 17th century carpets. This relationship suggests that the early phase of production represented by Field C0 occurred in a fairly localized environment given the similarities in weaving and dyeing features.

Objects R33.4.11 and 26.287 are important examples of transformations that occurred between the 16th and 17th centuries in carpet production. Sophisticated designs executed with a wide range of expensive dyes were maintained, while silk was replaced by cotton, making the carpets more economical, allowing for a decrease in production costs. The replacement of expensive materials with cheaper ones was one of the innovative responses from Iranian carpet producers to new demands – something that can be recognized in the objects in Group V 'New Carpets' (Figure VII. 3).

The term 'New Carpets' is used to describe objects in Group V, which production seems to develop from Early Safavid carpet production (Group III), due to 1) having similar a weaving structure, 2) including all the early version of Field C 'Vine scroll with Central Void and Clouds' and early 'Vine scroll with Central Void and Clouds - Sickle leaf' (Field D) and 3) sharing dye sources for red, yellow and orange colors. However, the reds display *Kerria* and/or kermes along with sappanwood as opposed to tannins. An increase in the number of yellow dye-sources is observed in yellows, oranges and browns (Appendix L).

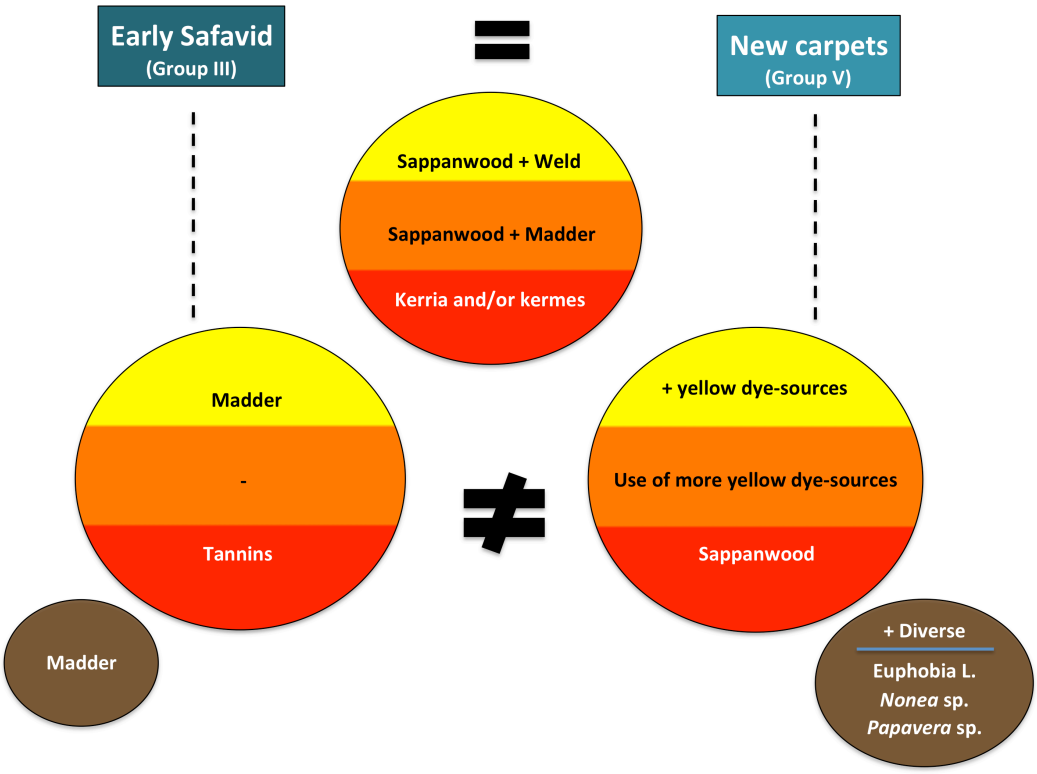


Figure VII. 3: Diagram presenting similarities and differences in dye practices between Groups III and V.

This increase in the variety of high quality yellow dye-sources indicates active experimentation in dyeing practices. The reason behind this appears to be achievement of new yellows, possibly to replace more expensive traditional yellows. Diversity and experimentation will become increasing characteristics in the evolution of the type. The change from a silk to a cotton foundation, while maintaining sophisticated designs, further reinforces the notion of innovation occurring between Group III and V, which from the analysis of designs presented in Chapter VI occurred between late 16th and mid 17th centuries. Despite the manifest efforts to reduce production costs, probably foreseeing a commercial purpose, the manufacture of these carpets still required sizable resources, skills and organization.

It is, however, significant to note that these 'New Carpets' are also appear to reflect two distinctive productions, probably aimed at different consumers. The first refers to carpets of large dimensions with sophisticated designs, displaying a coat-of-arms, and different color in the background of a densely field. Such distinctive features are suggestive of a special commission, therefore are termed as *Va – Commissioned carpet*. The latter also reveals unusual characteristics, which indicate commission, such as the green field and red borders as opposed to the traditional red field and green borders of the vast majority of these carpets. Both carpets are also densely decorated with sophisticated designs, achieved with a high-knot density superior to 3.000 knots per square decimeter (see carpets 15Tp and 84Tp in Appendix D). Such features are indicative of carpets commissioned to urban workshops interacting with court ateliers in Iran during the early 17th century (Figure VII. 1).

Large looms can manufacture carpets of smaller dimension, while the contrary is impossible. These large looms require sizeable investment and space, conditions that a small-scale workshop is unlikely to provide. Thus the production of these carpets had to occur in a well-resourced workshop.

A small carpet like 10Tp (see Appendix D) displaying field C - *Vine scroll with Central Void and Clouds,* which has a knot density that matches the large carpets previously described (3.025 knots per square decimeter), was probably made in a similar workshop. Interestingly, it also exhibits border f, recognized in European

paintings as early as 1598 (Appendices D and K), suggesting it could be dated to the early 17th century. All of these commissioned carpets (Va) show features that indicate a similar date and their high knot count and complex designs also reveal an interest in maintaining the high quality features of earlier production, which declines in later groups. Despite its smaller size, which allowed a significant decrease in the time of manufacturing, the quality maintained in carpet 10Tp indicates it was probably made to target a similar consumer, although at a reduced cost owing to its reduced size.

The other production within Group V, *Vb – Carpets in demand,* comprises carpets of various dimensions manufactured with a lower knot density – less than circa 2500 knots per square decimeter, characterized by an expansion in the number of combinations of field and border designs. These objects display later versions of Field C (C2, C3 and C4) and early versions of D (D0 and D1), with border designs establishing a mid 17th-century date for their production. Most significantly, a new motif – the sickle leaf, appears for the first time in examples of Field D. This motif will dominate later groups. In addition, this group witnesses an increase in the variation of dye sources used in comparison with Group III. Overall, carpets in *Vb – Carpets in demand* display new motifs and a wider range of dyes, together with a decrease in the knot count, suggesting that the weavers are actively experimenting in order to meet increase demand with cheaper production costs.

Finally, included in this Group V are two carpets attributed to India. These are easily distinguished from the other carpets in Group V by their weaving technique and designs, and do not imply an Indian origin for the entire Group. Indeed, one of them is extremely unique. It exhibits distinctive technical features (Z2S silk knots and Z7S-Z8S cotton foundation), silk and not wool in the pile and the red insect dye cochineal in the field. Cochineal would have been imported from Eastern Europe or the Americas, thus showing that Indian silk carpet workshops had access to luxurious dyeing materials. Cochineal has never been found in the 'Indo-Persian' group, further distinguishing this carpet from the rest of Group V. Yet, it has been found in

the silk Kashan carpets associated with court production in Iran.[7] This further emphasizes a more commercial context for the manufacture of the 'Indo-Persians'.

To summarize, the results from the group point to a proliferation of varied manufacturing practices around the middle of the 17th century something that continues in the next two Groups I and IV, which can be dated to the second half of the century (Figure VII. 1). To understand the transformations undertaken in manufacturing practices we start by comparing Groups V and I (Figure VII. 4).

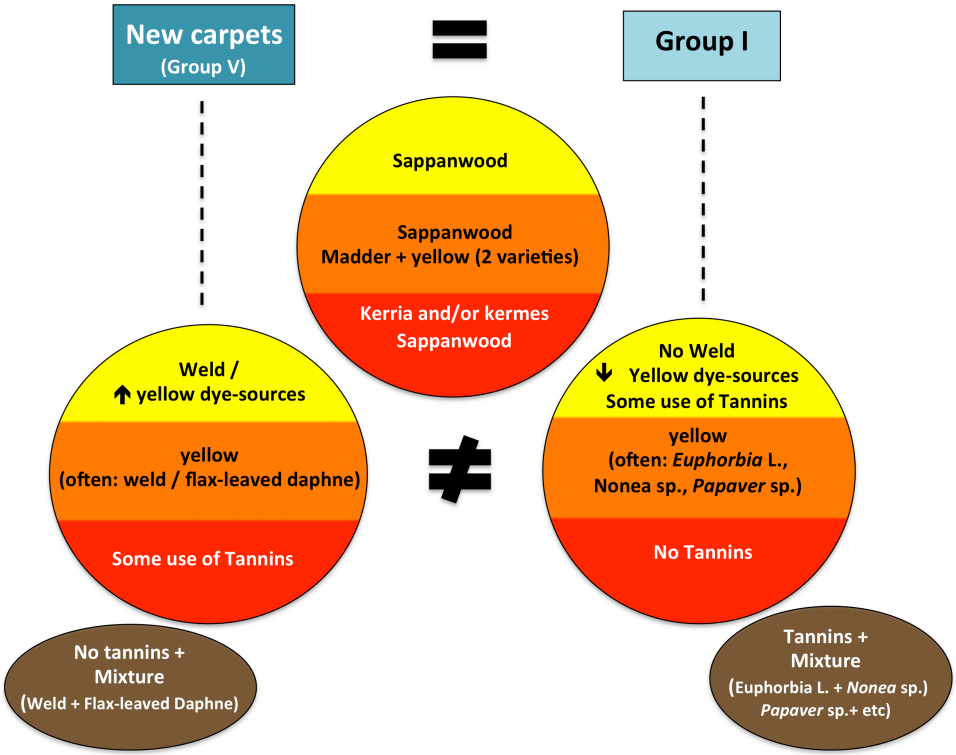


Figure VII. 4: Diagram presenting similarities and differences in dye practices between Groups V and I.

The 21 carpets in Group I share with V the use of sappanwood in red, yellow and orange colors. In addition, *Kerria* and/or kermes occur in the reds and madder in combination with two different yellow-dye mixtures in the oranges. However, objects in Group I are distinguished from Group V 'New Carpets', by the absence of weld and the inferior number of yellow dye-sources, and thus, distancing its dyeing practices from the earlier Safavid ones in which weld is consistently found. The inclusion of

[7] Hallett, 2007a, p. 43.

oranges in the color palette diminishes, with brown showing a very heterogeneous combination of dye-sources and the consistent presence of tannins.

The weaving techniques from carpets in Group I are very homogeneous and consistent with Iranian weaving traditions. Nonetheless, designs range from later developments of Field C (C3 and C4), and some variations of Field D (D0, D1 and D2), to Fields F and G. The latter, *'Tile Pattern – Quatrefoil Arabesque split-leaf'* and *'Large-scale geometrical networks of Vine scroll and Sickle leaf'*, are both suited for production of carpets of large dimensions appropriate for wealthy consumers and palatial settings (Appendix L).

This is the case for large carpets 48Tp and 67Tp with Field F and border k, which also share technical features. Both have the same combination of dyes for red and yellow colors and are found in Group I (Appendix L). The difference between the two objects is the combination of dye-sources used for the browns and the use of madder in oranges and browns from carpet 67Tp (Appendix L).

Interestingly, carpet 75Tp share the same field and border design, and dye combination in the oranges but with no browns in the color palette, which indicates: 1) that a single workshop producing provided similar designs with different color palette or 2) that urban workshops very closely were exchanging designs, but using their own choice of color palette. In addition, the dye-sources used in the yellows from 75Tp include weld and tannins, thus increasing the differences between dyeing practices amongst the alike, and placing carpet 75Tp in Group IV instead (Appendix L). We will be looking closer into Group IV shortly; nevertheless, together the results from the three objects (48Tp, 67TP and 75Tp) are suggestive of a manufacture in the same workshop or different workshops working closely (See Appendix D and L). Moreover, due to their large dimensions an urban workshop with the necessary human and technological means for their production seems likely. Noteworthy, seems to be the fact that carpets 48Tp and 75Tp sharing identical borders (border k), and especially inner minor borders are seen in objects found in different groups. Thus, denoting that the study of minor borders may not be sufficient to determine an object's origin or association to a specific workshop.

Another interesting case of related carpets includes objects 26.277 and T759, which indicate that border i is often used in carpets of large dimension and with earlier developments of Field D (see Appendix D). The creativity of this new composition is visible particularly in the famous *Lafões* carpet (26.277) displaying large sickle leaves. As suggested by previous authors,[8] the mirror image compositions of the large sickle leaves creates shield shapes, possibly inspired by the traditional shield of European coats of arms, seen for example in carpet 84Tp (Figure VII. 8), suggesting that the field design was specially created. Certainly, its enormous length of nearly fourteen meters indicates that it was produced for a palatial setting and wealthy client.

Lastly, another particular object in Group I is carpet T756 with a very questionable design.[9] In this work its field is appointed to the last development of Field C (C4) (see Chapter IV), yet its border (j) attributes its production to circa 1650 (see Chapter VI), which supports a mid 17th-century date for the manufacture of carpets in Group I.

When we compare dyeing practices between Group I and IV the shared use of sappanwood in red, yellow and orange colors, and *Euphorbia* L., *Nonea* sp., *Papaver* sp. and *Prangos* sp. exclusively in the yellows (see Figure Appendix L). There are, however, significant differences in dyeing practices for each of these colors. In Group IV the reds include the use of tannins and the yellows can be distinguish by the inclusion of weld, madder, tannins and *Populus* sp. (Figure VII. 5).

The inclusion of weld and madder in the yellow dyeing practices are similar to what we found in the earlier Groups III and V with Iranian dyeing practices. Thus, the eleven carpets from Group IV show a close proximity with traditional Iranian production. This notion is reinforced by madder in the oranges, as well as the use of a single yellow recipe that includes weld with madder, something already observed in Group III for Early Safavid carpets (Figures VII. 3 and VII. 5). In contrast oranges in Group I show two varieties of yellow, together with madder and sappanwood (Figure

[8] Hallett, 2010, p. 112-115.
[9] Ellis, 1972, p. 280; Ydema, 1991, pg. 87; Hallett, 2007c, p.103.

VII. 5). The brown recipes are easily distinguished from Groups III and V, developing into very heterogeneous combinations.

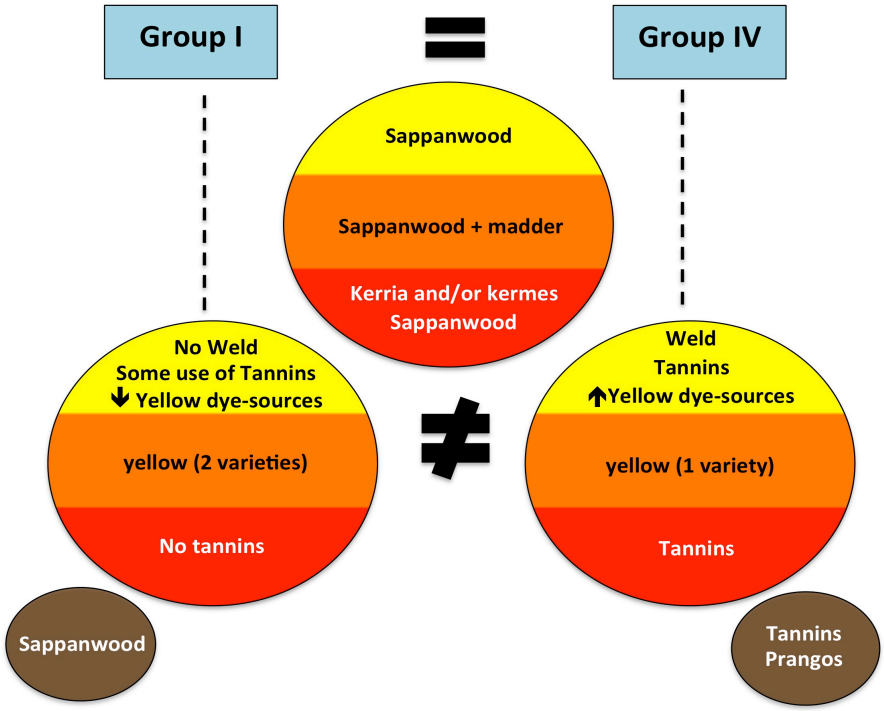


Figure VII. 5: Diagram presenting similarities and differences in dye practices between Groups I and IV.

The weaving techniques between Group I and IV are also very similar (see Appendix L). As observed in carpets displaying border k, the design analysis revealed that carpets displaying border c appears consistently with field C2 (classical 'Indo-Persian' design – Chenar leaf) in three carpets (see Chapter IV). Two of them (11Tp and 28Tp) found in Group IV show a matching combination of dyes (see Table IV. 16). Despite sharing the same dye-sources the third object (18Tp) is included in Group V, due to their use in different combinations. Nonetheless, their technique and material analysis indicates an Iranian origin, likely from the same workshop or different workshops working in a close environment. Moreover, carpets 11Tp and 18Tp with different dye combinations display identical minor borders, which fosters the idea that the use of a single carpet design or composition is insufficient to reliably establish origin.

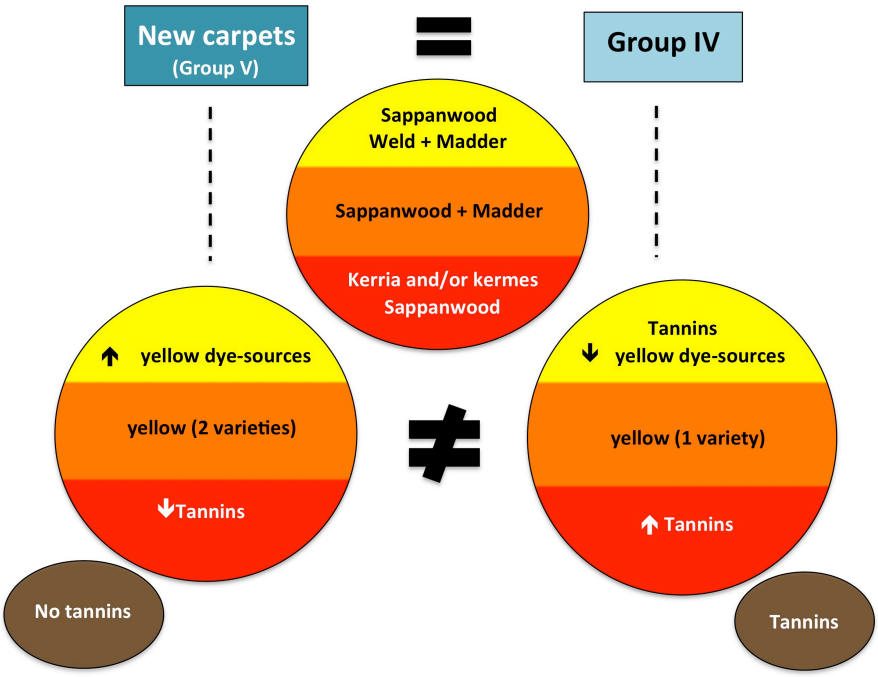


Figure VII. 6: Diagram presenting similarities and differences in dye practices between Groups V and IV.

Finally, the relationship between Groups V and IV builds on their similarities in red, yellow and orange dye-practices (Figure VII. 6). Important is the fact that the number of yellow dye-sources used in Group V, decreases in Group IV (something already observed before in Group I), while maintaining the use of weld and madder in yellows and oranges, established before as typical characteristic of early Iranian carpet production. Moreover, browns from Group IV have two varieties of yellow in combination with tannins (Figure VII. 6).

Based on this methodology the remaining five objects (T746, T750, T754, T756, and 27Tp) can now be associated with different productions. In addition to silk warps, sophisticated designs accomplished using a high-knot density (c. 4.000 knots per square decimeter), carpet T746 shares yellow dyes-sources with carpets displaying earlier fields design (Field A) and can therefore be associated with early Iranian production - Group III. Carpet fragments T750 and T754 share the pink background fields and border f. In both cases, the pink color shows the use of sappanwood while yellows in T750 can be associated with early 17th-century dyeing practices in Group V. In the latter case (T754) the use of tannins in the yellows, together with the later development of field D suggests that it can be attributed to later production, most likely Group I as no weld as detected. Likewise, despite their

distinct field and border designs, the production of carpets T756 and 27Tp can be related with Group I and thus these objects were likely manufactured during the mid 17th century in the midst of experimentation in designs and dyeing practices.

To summarize, together these results indicate that Group V 'New Carpets' appears to confirm continuity between dyeing-practices from the Early Safavid type (Group III), but with considerable innovation in regard to mixing yellow dye sources. Indeed, the maximum number of different yellow dye sources used in a single dye bath occurs in Group V. Significant differences are also observed in fibers and designs; silk in Group III is replaced by cotton in the foundation of V, and the sophisticated animal designs are transformed into exclusively floral representations. These developments can be dated from the chronology of designs presented in Chapter VI as occurring between the late 16th and early 17th centuries, reinforcing that these initial innovations occurred during the reign of Shah Abbas. In addition, carpets T747 and 26.287 in Group III share similarities in weaving and dyeing features. Both also display Field C0, the earliest of *Vine scroll with Central Void and Clouds,* suggesting that the initial phase of carpet production with Field C occurred in a fairly localized environment in Iran, probably in a city or town.

Group I and IV are later developments. Here, the number of yellow dye sources used in a single dye bath is reduced, but the number of combinations between them increases to produce new yellows not seen previously 'New Carpets' (V) and, when occurring, also new oranges. This development indicates that the innovations of Group V, involving a great variety of dye sources, were followed by experimentation with combining them to create new dye recipes and different yellows in Groups I and IV. From the painting evidence this transition can be attributed with confidence to the mid 17th century. Moreover, the use of weld and madder for yellows and oranges in Group IV, which are also found in the Early Safavid manufacturing traditions (Group III), indicates that objects from Group IV were likely produced in Iran, as opposed to India.

The pattern observed above - in which the 'New Carpets' (V) display the maximum number of colors and dye-sources is followed by a reduction in the variety of these dye-sources but their use in more varied combinations in I and IV - is also

seen in the designs. Namely, the intricate network of vine-scrolls with numerous small motifs in the field develops into large-scale designs with new motifs, together with an increase in different combinations of borders and fields, leading to a wide variety of carpet designs. This transformation can be traced in carpets of the *Vine scroll with Central Void and Clouds* type, in which Fields C0 to C3 using the traditional motifs found in Early Safavid carpets is transformed in C4 with the introduction of a new element: the pinwheel rosette, which is followed by other motifs such as the sickle leaf in field D. This transition can be dated to around the mid 17th century from the painting evidence (Chapter VI).

This expansion of dyeing practices and designs used in carpet manufactures from the mid 17th century is consistent with experimentation and proliferation in production, and seems to indicate the rise of multiple workshops. The question of the scale in which they were working is difficult to determine and the context could be: 1) a single city or town, 2) a wide region, or even 3) multiple regions. From the dye sources in Group IV, which are close to Early Safavid carpets (weld and madder), it seems that their production occurred in the same location as Groups III and V. The presence of border c in Groups IV and V (also associated with III) further confirms this relationship. By contrast, Group I has different yellow dye sources (no weld or madder) and also includes a specific design type, namely Field G (*Large scale geometric vine scroll and sickle leaf*). Otherwise, it relates to Group IV. These comparisons link Groups III, V and IV but distinguish Group I, suggesting that the first three reflect reasonably localized production in a city or region of Iran, while the location of Group I remains uncertain and could even be Indian, as discussed further below. As far as the region of production for III, IV and V, it seems reasonable to exclude production in northeast Iran. Narrowing these attributions to a specific city or region requires understanding more about local dyeing practices in cities like Isfahan, Kerman or Yazd.

Unfortunately, such a study requires historical objects for which origin is confirmed, which as discussed in Chapter II is extremely rare. One carpet that is of extreme importance in this respect is the Mashhad carpet, discussed below, as it could help to indicate a link with Kerman for their production. In addition, the

examination of Persian sources can be of immense importance as has seen for the arts of the book, regarding the precise materials and working methods use by the various personnel required to textile manufacture, in particular dyeing master, as their knowledge was often passed to a very limited number of individuals, often transmitted only among family members.

Additionally, it is important to observe that the use of a single carpet design or composition is insufficient to reliably establish origin, as proven by the example of carpets 11Tp and 18Tp with identical minor borders but with different dye combinations in the yellows. A weaver working in an urban workshop producing these commercial carpets was likely to have a voice in the execution of a pattern or even in the choice of colors, but not in the dyeing practices used to achieve them. This was the responsibility of the master dyer with his specific knowledge, and reinforces the importance of color studies for understanding the historical context of production practices. And for evaluating whether this occurred in a single workshop or multiple ones.

From the dye results, it is possible to establish the exclusion of the use of madder or orange, in the color palette of Indian carpets from the 17th century. This information, together with the consistent use of local yellow dye-sources, such as young fustic, turmeric and flame of the forest, represent significant evidence for diagnosing an Indian origin for production. In addition, Indian carpet 26.286, includes the use of silk and the red insect dye cochineal, also found in Early Safavid silk 'Kashan' carpets,[10] shows that Indian workshops also had access to luxurious dyeing materials. Neither of these two materials was found in the *Vine scroll with Central Void and Clouds* carpets, or in the cotton and wool Indian carpets (1Tp, 12Tp, 53Tp, 71Tp, 26.297, R63.00.15). Both types also share the use of *Kerria* sp., kermes, tannins and sappanwood in red and pink colors, confirming that carpets with wool and cotton represented distinctive manufacture traditions in both Iran and India from silk carpet production. These dye-sources are recognized to occur in areas

[10] Heitor, 2007.

ranging from West to South and Southeast Asia. The use of sappanwood[11] is identified for the first time here in association with 17th-century Iranian and Indian carpets. Moreover, in addition to suggesting an exchange of knowledge in dyeing practices between Iran and India, its presence can indicate that there was an increase in the circulation of dye sources, possibly as a result of the increased volume of the overseas textile trade in Asia at this time.

The results obtained from carpet T753, the only carpet of the *Vine scroll with Central Void and Clouds* type included in Group II 'Indian carpets', based on the dyes found, which include madder and weld, seems to support this kind of exchange. Moreover, despite displaying border f – one of the most popular seen in combination with Fields C and D, the *ton-sur-ton* effect seen on both the light green inner minor border and green major border, and the pink horseshoe-shaped clouds against the red field, suggests that carpet T753 could be an example of *Vine scroll with Central Void and Clouds* produced by Iranian weavers working in India.

Likewise, carpet T756 in Group I also presents the *ton-sur-ton* effect, which in addition with its unique design with a flaming diamond medallion and a single vine border has been used as an argument for a attributing it to India.[12] Charles Grant Ellis considered it to be an Indian copy of the so-called 'Indo-Persian' type (with floral and cloud band design) "largely exported to Portugal, Spain and Netherlands".[13] As disclosed here such an argument based exclusively on design is not in itself sufficient for determining origin. However, the absence of any madder from orange or yellow colors established by this study seem to support such attribution. On the basis of its design, it is appointed to the last development of Field C (C4) (see Chapter IV), but its border (j) attributes its production to circa 1650 (see Chapter VI), indicating a mid 17th-century manufacture date.

The results have appointed carpet T756 to a production that develops from 'New Carpets' (V), in which experimentation occurs by reducing the number of yellow

[11] Known to be native to the region between central and southern India through Burma, Thailand, Indochina and southern China to peninsular Malaysia (see Chapter V).
[12] Mills, 2007.
[13] Charles Grant Ellis considers this carpet to be an Indian copy of the so-called 'Indo-Persian' (with floral and cloudband design) largely exported to Portugal, Spain and Netherlands. See Ellis, 1972, p. 280.

dye-sources, which are used together in additional combinations and where madder and weld – associated with Iranian dyeing traditions, are totally absence from the palette. This fact together with existence of carpets displaying the latest developments of field designs (F and G) - with large-scale motifs, lower knot density, and a more limited color palette and range of dye-sources (Appendix L) - places carpets in Group I, including carpet T756, further away from Iranian attribution. Therefore, the design and color features, and the dye analysis performed seem to suggest T756 is the result of a later production with access to dye-sources used used in Iranian in early 17th-century, but likely adapted into new less elaborated combinations in workshop outside Iran.

Together the results from the 59 carpets attest to two different moments in carpet production. The first, *innovation,* occurred between the late 16th and early 17th centuries and the second, *experimentation*, happened around the mid 17th century onwards. The five groups previously characterized represent different moments (and possibly places) in a century-long carpet manufacturing tradition. Moreover, they attest that in addition to the production of high-end carpets made of precious materials that include silk, metal thread, large color palette achieved with expensive dyes, with the display of sophisticated designs, Safavid carpet industry developed into new and more affordable carpets of significant dimensions and large-scale motifs, preserved the quality recognized from Iranian carpet industry. In the following section we will look into how carpet industry developed during this period to fit the demands of different consumers, and how 'Vine scroll with Central Void and Clouds' (Fields C and D) represent commercial carpets intended for export.

VII. 2. Consumption

The majority of the so-called 'Indo-Persian' carpets have a wool pile and cotton warps and wefts. The introduction of cotton in the carpet structure, as opposed to silk, was the first step to decrease manufacture costs and make them more affordable export products. Thus, in order to follow their consumption we must start by looking at the production of high-end carpets. This section will begin by focusing on five objects, each representing distinct moments in carpet production during 16th

and 17th centuries: 1) the *Mashhad carpet* (Figure VII. 7); 2) the '*Vine scroll' carpet with unidentified coat of arms* (Figure VII. 8); 3) the large *'Vine scroll with Central Void and Clouds'* carpet (Figure VII. 9), 4) the '*Lafões*' carpet (Figure VII. 10) and finally, 5) the *Tile Pattern – Quatrefoil Arabesque split-leaf* carpet (Figure VII. 11).

The first object, the *Mashhad carpet,* belongs to the Carpet Museum of the Shrine of Imam Riza (Mashhad, Iran) (Figure VII. 7). Its design shows the complete absence of animal or human figures in the field, and is densely decorated with two sophisticated sets of vine-scrolls and floral motifs against a red background. The border shows in-and-out palmettes displayed diagonally, alternating with pairs of leaves. This design is adopted and further developed in '*Vine scroll with Central Void and Clouds'* carpets (Fields C and D).

The carpet exhibits a cotton and silk foundation and woven structure embellished with metal thread (wrapped around a silk core[14]), which makes it an exceptional carpet and distinctive from the Indo-Persians discussed so far in this thesis. This high-end wool pile carpet, measures approximately 5.60 meters in length by 3.50 meters in width, and has a knot count over 4.900 knots per square decimeter. Local tradition maintains that it was given to the shrine by Shah 'Abbas.[15] Additionally, as Thompson explains "indeed, Iskandar Beg Munshi records that 'sumptuous rugs of Kirman and Jushaqan' were sent there by Shah 'Abbas in 1598".[16]

Carpet production from the city of Kerman was well known during the 17th century for its quality. Yet, it is unclear from this description if any of the mentioned rugs correspond to the Mashhad carpet. Nevertheless, this information verifies that high-quality carpets were being produced outside Isfahan under Shah Abbas's patronage and served as royal gifts. It is also a reminder that we should not focus exclusively on Isfahan when attempting to establish an origin for the so-called "Indo-Persian" type, as has happened in much of the recent literature.

[14] Information gently provided by Dr. Jon Thompson.
[15] Canby, 2009, p. 192.
[16] Idem, p. 210.

Figure VII. 7: 'Isfahan' carpet with precious metal thread, offered to the Shrine of Imam Riza, Mashhad, by Shah Abbas. Iran, early 17th century, Carpet Museum, Shrine of Imam Riza, Mashhad (Iran). Photo courtesy: Dr. Jon Thompson.

The sophistication in design seen in the 84Tp carpet, can be perceived in the second carpet, '*Vine scroll' carpet with unidentified coats of arms* belonging to Museu Nacional de Arte Antiga (Lisbon, Portugal). This object with a wool pile and cotton warps and wefts is of similar dimensions (4.17 x 2.35 m) and is part of the group of carpets included in this study (Appendix D). On the basis of design analysis, it is attributed to the early version of Field C, *Vine scroll with Central Void and Clouds – Palmettes* (C1). In this particular field type large palmettes facing in-and-out along vertical axis play a significant role in the overall composition of a densely decorated field, together with the inclusion of an unidentified coat of arms. Moreover, its green field and red border presents this carpet as a variation from the traditional color scheme - red field and blue or green border, typically seen in Early Safavid carpets (Figure VII. 8).

Figure VII. 8: 'Vine scroll' carpet with unidentified coats of arms. Iran, 17th century, Museu Nacional de Arte Antiga, Lisbon.

Despite the absence of silk from its foundation and metal threads, its high quality can be perceived by the significant knot count of circa 3.300 knots per square decimeter. The design (coat of arms) and reversed color scheme are clear indication that it is a special order. Thus, this carpet, now associated with early 17th century, likely represents a commission from a wealthy aristocratic consumer with the financial resources, and undoubtedly good connections with Iran, either personally or by intermediaries, to allow him to obtain such customized.

Carpet 15 Tp *'Vine scroll with Central Void and Clouds - Palmettes'* t (Figure VII. 9, Appendix D) is related to 84Tp but has the more common red field and green border (Figure VII. 8). It also exhibits large dimensions (7.96 x 3.75 m), wool knots and cotton foundation. Its higher knot count (over 3.000 knots per square decimeter) is also responsible for the creation of the densely decorated and sophisticated designs, consistent with Field C1. Both carpets appear in 'New Carpets' (V) consistent with the period of innovation that led to the new type. Noteworthy, is the fact that this object has been cut in the past, likely to make it more suitable to a particular space, and thus would originally have been much longer than its current approximately 8 meters. This seems to support it was made for a wealthy consumer with the necessary floor space and economic means to acquire it.

Figure VII. 9: 'Vine scroll' carpet. Iran, 17th century, Museu Nacional de Arte Antiga, Lisbon.

The '*Lafões*' carpet (13.49 x 4.32 m), similarly, represented a substantial investment (Figure VII. 10 and Appendix D) and from it history it is possible to establish with more accuracy the intended consumer. It has a well-known provenance. Before being sold in 2014 as part of the collection from the former Corcoran Gallery of Art, it is documented to have belonged to Caetano Seismundo de Braganca (1856-1927), Duke de Lafões, and illegitimate brother of King Joao V (r. 1707-50).[17] Such exceptionally well-recorded provenance places this object in aristocratic, and possible even royal, hands.

[17] Further details on this matter can be found thoroughly discussed in Hallett, 2010, pp. 115-116.

Figure VII. 10: '*Lafões*' carpet with unidentified coats of arms. Iran, 17th century, Museu Nacional de Arte Antiga, Lisbon.

The design analysis undertaken in this study attributes this carpet to Field D2 - *Large-scale Vine scroll with Central Void and clouds – Sickle leaf*, a later development of Field D, due to the display of large-scale motifs, where the sickle leaf becomes a predominant element of the design of both the field and borders, in contrast with design in Field C. The design chronology developed in this work dates its production to the second half of the 17th century where the scale of motifs is seen to increase, thus making it later than the objects discussed previously here.

The '*Lafões*' carpet is also made of wool pile and cotton foundation but its large-scale designs are woven with a lower knot density, reducing the production times so the workshop could respond faster to the demands for large carpets. On behalf of its large size it is tempting to postulate this object was commissioned to fit a special space in a palatial setting. However, no evidence has yet come to light to identify it.

These four carpets demonstrate a trend in production beginning with a carpet involving a sophisticated design and precious materials, commissioned by Shah Abbas, followed by the manufacture of related versions in cheaper materials but maintaining as much as possible the complexity of the designs, and finally by a

carpet which combines large dimensions with large-scale motifs in simplified design compositions. The latter could be achieved with a lower knot density, thus reducing time and cost. Its colors also involve fewer dye-sources which are used in more varied combinations and associated with the period of experimentation. This latter phenomenon occurs in the mid 17th century and is accompanied also by experimentation in designs (Groups I and IV).

This phase seems to indicate an increased demand for these knotted-pile carpets, possibly in response to a flourishing international interest, which include European consumers. The extent of time and money invested in the manufacture of the 'New Carpets' must have naturally limited their availability. Hence, the interest in varying designs but also the concern with lowering the cost involved by decreasing the knot count and therefore the number of hours of labour. This interest in large dimension carpets, led to the development of tile-pattern designs executed in rows, which allowed endless variations just by changing motifs and color scheme, hence fulfilling demands for carpets of any length in a faster manner (Figure VII. 11).

Figure VII. 11: 'Quatrefoil arabesque' carpet. 17th century, Museu Nacional de Arte Antiga, Lisbon.

These carpets were without doubt symbols of enormous prestige only within reach of privileged people. The '*Lafões*' carpet can be related with Portuguese personalities belonging to royal or aristocratic circles. These 16th and 17th century carpets are most frequently depicted as objects in the floor of a royal space, either

under the feet of a king or queen (Figure VII. 12) or flooring the room of a princess (Figure VII. 13).

Figure VII. 12: *Saint Francis Xavier bidding farewellto D. Joao III before leaving to evangelize India,* c. 1619. Andre Reinoso, Church Sao Roque, Museu de Sao Roque, Portugal. Published by: Hallett, 2007.

Figure VII. 13: *Birth of Princess Santa Joana*, c. 1720 Manuel Ferreira e Sousa, Museu de Aveiro, Portugal. Published by: Hallett, 2007.

Moreover, in Portugal the majority of these carpets are derived from convents or churches - as a donation from noble families, where they were also used as floor covering in the past.[18] In contrast, Dutch paintings regularly portray their use as table covers in the households of bourgeoisie families and in the group portraits of guilds or aristocracy (Figure VII. 14), with the largest number of depictions occurring in the third quarter of the 17th century.[19] In this thesis we have observed that there is an expansion in production in the middle of the 17th that involves experimentation, probably linked to an increase in demand, and the painting evidence as well as the large numbers of existent carpets in Portuguese collection suggests that it may have come from Europeans consumers.

To conclude, the introduction of cotton represents a significant step for decreasing manufacturing cost to create

Figure VII. 14: *Lambert Twant and his Four Sons* (115 x 138 cm). 1695, Court, M. de la. The Hague, the Netherlands.

[18] Hallett, 2007, p. 91.
[19] Idem, p. 91.

more affordable carpets. This innovation had repercussions perceived in knot count and design, which moves gradually from dense and sophisticated patterns of small-scale motifs into new simplified compositions of large-scale motifs using less knot density. This allowed the decrease in production time, while in parallel, the increase the of numbers of carpets produced to respond to new consumers in search of carpets of quality of large dimensions and appealing design and colors. As a result, the incentive given to workshops by new international markets, and possibly Europeans consumers, seems to have encouraged them to experiment, resulting in the proliferation of dyeing practices and designs used for carpet manufacturing in the mid 17th century.

CONCLUSION

This dissertation uses an interdisciplinary approach – Art History, History and Materials Science combined – to understand if 'Indo-Persian' carpets were products developed for export and to establish the role played by consumers in encouraging the creation of new types of carpets. It defines sustained criteria for establishing groups of carpets within the *Vine scroll with Central Void and Clouds type.* Moreover, it presents new designations for the various designs recognized and offers a window onto how Iranian and Indian carpet production developed and adapted to accommodate the demands of new markets and consumers in places like Europe between the 16th and 17th centuries. It argues that so-called 'Indo-Persian' type is a commercial response from the Islamic carpet industry to new markets as result of the new maritime trade and the resultant increase in demand from European elites.

The use of Islamic carpets as historical evidence is of vital importance to understand the origin of *Vine scroll with Central Void and Clouds* carpets, especially as historical sources appear to be silent on this subject. Likewise, the selection of historical objects with distinct designs and geographical attributions is fundamental to recognize developments in carpet production during the 16th and 17th centuries, particularly between the 'Early Safavid' and 'New carpets', in which the *Vine scroll with Central Void and Clouds* carpets are encompassed.

The survey of the 59 objects belonging to Museu Nacional de Arte Antiga and Museu Nacional de Machado de Castro (Portugal), and The Textile Museum, The National Gallery of Art and the former Corcoran Gallery of Art, all based in Washington, DC, involved study of their field and border designs, technique and materials. The analysis of their designs identified twelve major border groups correlated with the eight fields, and their variations. From this, two significant observations emerge: firstly, some borders appear with a very limited range of field

designs suggesting that these carpets were made in a localized setting – a workshop or town; secondly, other borders appear to have been more popular and were combined with multiple field designs. This situation can be interpreted in two ways: 1) by transmission of designs between multiple workshops working closely in a large city or wider region, or 2) by an increasing creativity through design experimentation to meet market demand. In addition, this analysis has provided new labels to refer to the various designs previously described under the 'Indo-Persian' designation.

Looking at their depictions in approximately 230 Portuguese and Dutch paintings further refined the relative chronology proposed from the analysis of the designs. Only ten major border types can be related to depictions from Portuguese and Dutch paintings of known date. Nevertheless, the relationships between border types from extant carpets and 16th- and 17th-century paintings allowed the establishment of *termini ante quem* dates for the majority of border types.

The combination of designs with relative and *terminus ante quem* dates reveals the rise of a small number of initial designs mainly with palmettes, cloud bands and chenar leaves at the end of the 16th and beginning of 17th centuries, which was followed in the middle of the 17th century by a growth in the variety of designs and the emergence of an entirely new group, namely with sickle leaves in the field and border. The evolution from a small number of designs to a much wider variety raises a number of questions, and demonstrates how date and origin are problems that are intrinsically related. It stresses the importance of addressing these problems together when studying historical carpets.

Carpets are products of a complex chain of operations, some of which can remain fixed for long periods while others can change suddenly or evolve with great speed. Consequently, attempting to solve problems of origin it is not complete without considering the broader context of their production, and this requires looking at technique, fiber and dyes.

Often the state of conservation of historical carpets or carpet fragments present limitations such as the absence of features such as edges, sides or ends. This fact has a direct impact on the completeness of information to ensure a high level of consistency

in the weaving analysis. Consequently, the most consistent method for comparing different woven structures is to rely on the observation of three main features: pile, warps and wefts. The examination of carpets based on these three elements allowed for the establishment of seven groups. The largest group comprises 46 of the total 59 objects in this study, and includes all *Vine scroll with Central Void and Clouds* carpets made following Iranian weaving traditions. Thus, establishing further carpet geographical attributions requires combining these results with others from material analysis of fibers and dyes.

Results from both longitudinal- and cross-sections of 16 historical samples were able to confirm the type of fiber. For all the examined samples wool was used for the carpet knots and cotton for the foundation (warp and weft). Unfortunately, it was impossible to differentiate the precise animal species of the wool due to the lack of reference materials, and small sample amount. Moreover, the examination of the physical properties of the fibers using optical microscopy did not enable further refinement beyond identifying wool and cotton. Thus, additional methods for fiber analysis are required. Given the limitations imposed by historical textile samples, it seems that fiber DNA sequencing may be a promising next step in the future to further refine the interpretations presented here.

A total of 762 historical wool samples from red, pink, yellow, orange and brown colors were collected for the purpose of associating these objects with specific workshop locations. Over 800 carpet analyses were conducted and the results analyzed using LC-MS technique and interpreted on the basis of multivariate statistical analysis. Dyes identified in red and pink colors indicate the use of red insect dyes for carpets attributed to 'Early Safavid' and 'Indo-Persian' types (table III. 7): *Kerria* sp. alone or in combination with *Kermes* sp., as well as tannins and sappanwood. No red insect dyes were found in the orange samples from 'Early Safavid' and 'Indo-Persian' carpets. Instead, oranges samples have a mixture of madder (*Rubia* sp.) and a yellow-dye exclusively. The results indicate that the inclusion of madder in yellow or orange historical samples can be exclusively associated with 'Early Safavid' and 'Indo-Persian' dyeing practices. No madder compounds were found in Indian carpets. Together these

results are consistent with previous studies on Iranian carpets in Portuguese collections, reinforcing the idea that this color combination is characteristic of a classical Iranian palette.[1]

By contrast, the number of dye sources recognized in yellow colors is significantly higher than what has been reported to date for Safavid carpets. For the first time, results from yellow samples suggest in addition to weld, the use of the following dyes: *Euphorbia* sp., *Papaver* sp., *Prangos* sp., *Nonea* sp., Anacardiaceae, *Populus* sp. and flax-leaved daphne.

Additionally, sappanwood, madder and tannins were identified in a large number of these yellow samples, which indicates they were present in the dye-bath, presumably as an intentional addition by the master dyers. With the exception of madder, found solely in deeper yellow hues, the intended use of sappanwood and tannins in yellow dyeing is unclear. However, one can speculate that they were used as a fiber pre-treatment or as a mordant. Similarly, the use of red insect dyes were found in reds and pinks found in Indian wool pile carpets (*Kerria* sp. alone or in combination with *Kermes* sp., as well as sappanwood). The exception is the silk pile carpet (26.286) in which cochineal and *Kerria* were found together in the reds. Likewise, the combination of sappanwood, *Euphorbia* sp., *Papaver* sp. and *Nonea* sp. are found together uniquely in this object. The use of expensive red insect and yellow plant dyes in the silk fibers suggests a distinct production location, most likely a well-resourced workshop in close proximity with the Mughal court.[2]

The use of tannins in reds does not appear as consistent as in 'Early Safavid' and 'Indo-Persian' carpets. In contrast, in Indian carpets tannins are identified consistently in yellows, together with young fustic, turmeric and flame of the forest. Furthermore, such combination in yellows appears to be a common dyeing method for wool pile carpets across the different regions of the Indian subcontinent, including Golconda or Lahore.

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[1] Santos, 2010.
[2] This is reinforced by recent studies: Serrano, 2016, pp. 116-118.

Studies to identify natural dyes in historical textiles have come a long way over the past decade, but various obstacles for associating dye compounds with specific dye-sources remain, as seen also in other recent studies. [3] The colorant composition is directly related to the type of fiber, dye, and the different dyeing parameters applied, which together cause different reactions during the dyeing process resulting in different dye compositions.

The chromatographic results obtained provide a window into 'Early Safavid', 'Indo-Persian' and Indian dyeing traditions during 16th and 17th centuries. The different combinations of red and yellow dye-sources used together in the carpets in this study support the existence of multiple dyeing practices. This result permits differentiation of carpet production geographically, namely to Iran or India, based on the analysis of their dyes. Five clusters of objects were determined by means of combined PCA analysis of the chromatographic results from 54 historical objects.

This study adds to the group of known dye sources previously documented to compose the color palette of carpets attributed to Iran. In addition to *Kerria*, weld, madder and tannins, reported to occur in red, pink, yellow, orange and brown colors, other dye sources are now known to be used in Iranian carpet production during the Safavid period from 16th to 17th centuries. The results allow discernment of the level of sophistication of carpet manufacture based on the assortment of dye sources selected. Furthermore, data from materials identified and their sources and stylistic data offer a way to characterize production while distinguishing carpet groups.

The results show that Group V 'New Carpets' confirms continuity between dyeing-practices from the Early Safavid type (Group III), but with considerable innovation in regard to mixing yellow dye sources. Indeed, the maximum number of different yellow dye sources used in a single dye bath occurs in Group V. Significant differences are also observed in fibers and designs; silk in Group III is replaced by cotton in the foundation of Group V, and the sophisticated animal designs are transformed into exclusively floral representations. These developments can be dated

[3] Serrano, 2015, p. 125.

from the chronology of designs presented in Chapter VI as occurring between the late 16th and early 17th centuries, reinforcing that these initial innovations occurred during the reign of Shah Abbas. In addition, carpets T747 and 26.287 in Group III share similarities in weaving and dyeing features. They also both display Field C0, the earliest of *Vine scroll with Central Void and Clouds,* suggesting that the initial phase of carpet production with Field C occurred in a fairly localized environment in Iran, probably in a city or town.

This expansion of dyeing practices and designs used in carpet manufactures from the mid 17th century is consistent with experimentation and proliferation in production, and seems to indicate the rise of multiple workshops. The question of the scale in which they were working is difficult to determine and the context could be: 1) a single city or town, 2) a wide region, or even 3) multiple regions. Thus, proving that analysis of materials and design can be used to further understand the context surrounding production. However, narrowing these attributions to a precise city or region requires understanding more about local dyeing practices in cities like Isfahan, Kerman or Yazd.

Such a study requires historical objects for which origin is confirmed, which as discussed in Chapter II is extremely rare. One carpet that is of extreme importance in this respect is the Mashhad carpet, as it could help to indicate a link with Kerman for their production.[4] In addition, close examination of Iranian (and Indian) sources could be of immense importance as has been seen for the arts of the book, regarding the precise materials and working methods used by the various personnel involved in textile manufacture, in particular the master dyer, as their knowledge was often passed to a very limited number of individuals, and often transmitted only among family members. Moreover, it is important to observe that the use of a single carpet design or composition is insufficient to reliably establish origin, as proven by the

[4] Please see figure VII. 7 and Canby, 2009, p. 210.

example of carpets 11Tp and 18Tp which have identical minor borders but different dye combinations in the yellows.

This dissertation observes the rise of a new type of carpet at the end of the 16th century under Shah Abbas and then a rapid expansion in production in the middle of the 17th that involves considerable experimentation. In the first phase, the introduction of cotton represented a significant step for decreasing manufacturing cost to create more affordable carpets. This innovation had repercussions on the knot count and design, which moved gradually from dense and sophisticated patterns of small-scale motifs into new simplified compositions of large-scale motifs using less knots. This decreased the time necessary for their production, while in parallel, increasing the numbers of carpets that could be produced in the same time and making large carpets easier and faster to manufacture. This innovation appears most likely to have been something that was initiated inside Iran to attempt to capture a new market and part of Shah Abbas's programme to promote the Iranian export trade.

The experimentation seen in the combinations of dyes and designs that occurs in the middle of the century suggests expansion in manufacturing, which was linked to an increase in demand for carpets with appealing design and colors from outside Iran, and the painting evidence indicates that it may have come from Europeans consumers. This increased demand from Portuguese and other European consumers, who desired for luxury textiles from overseas,[5] spurred the carpet workshops to experiment. This resulted in the proliferation of dyeing practices and designs used for carpet manufacturing in the mid 17th century. Together such evidences indicate that the profitable prospects prompted by the interest of new markets, were certainly offering confidence to carpets weavers in smaller scale businesses to take higher risks and be more enterprising in producing appealing carpets.

This dissertation attests that production of *Vine scroll with Central Void and Clouds* between the 16th and 17th centuries was encouraged and developed in a

[5] Further reading other textiles for export: Ferreira, 2015; Karl, 2016.

response to international trade. It stresses the importance of multidisciplinary methods for providing answers to the study of historical carpets, opening new horizons around the study of historical textiles. In addition, it encourages continuous development of analytical techniques to the improve the study of fibers and dyes, and the examination of Iranian and Indian sources to obtain further information on the precise materials and working methods use in textile manufacture in the 17th century. In the future it would be interesting to compare the observed evolution in carpet production here with other Asian historical textiles made for export, such as Chinese and Indian embroideries, or printed, painted and batik cottons, to understand if the mid 17th century represents a phase of proliferation and experimentation common elsewhere, to meet increasing demands from Europe.

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