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## Historical and Scientific Analysis of Iranian Illuminated Manuscripts and Miniature Paintings<sup>2</sup>

The present study aims to identify the materials and techniques used in Persian illuminated manuscripts and miniature paintings and its major significance in comparison with Indo-Iranian and Mughal paintings. The research methodology was based on oral interviews with traditional masters, historical analysis and scientific analysis.

During the historical survey over 30 Persian historical treatises from the fifteenth to the nineteenth centuries (i.e. from the Timurid through to the Qajar period) were collected and studied. All the recipes from these treatises were categorized and the information was used as the basis for scientific analysis.

Scientific analysis to reveal the materials used in different paint layers of Persian miniature paintings was carried out. For this task, twelve selected illuminated manuscripts, miniature paintings and paint boxes from the sixteenth to late nineteenth century were collected. For comparative analytical research, an Indo-Iranian miniature painting, as well as two paintings belonging to the Mughal period were also collected and added to the samples as the references.

The objective of the present research was to identify the materials and techniques used in Persian illuminated manuscripts and miniature paintings and its major significance compared to Indo-Iranian and Mughal paintings.

The research methodology was based on three approaches. The first consists of a series of interviews carried out with the artists from Iran and India. The traditional Iranian masters such as: Sani'ei, Jazizadeh, Takestani, Harati were among these artists. The second method was historical analysis, by collecting the Persian historical documents and treatises on the recipes and techniques from Timurid, Safavid, and Qajar periods. During the historical survey the historic documents, including over 30 historical treatises (such as *Golzār-e safā*, *Adāb ol-mashq*, *Resāle dar bayān-e khatt-e morakkab va hall-e alvān*, *Favāyed ol-khotut*), were collected and studied.<sup>3</sup> These sources are related to the materials used in the art of bookmaking and painting from the Timurid to the Qajar period, such as different techniques of making dyes for paper colouring, pigments and dyes used as paint, binding mediums, sizing materials, burnishing techniques, and so on. All the recipes were collected and categorized and the information was used as the basis for our scientific analysis. Historical data on techniques was collected for the most commonly recommended dyes, sizing materials, pigments, etc. that may have had a major role in the stability of the Persian paintings as a case study for further analytical research.

Finally, the third technique was the scientific analysis from original samples selected from Irān-e Bāstān Museum, private collectors and traditional artists. The Safavid miniature paintings in the Irān-e Bāstān Museum collection, primarily from Iran and India, include a wide range of dates and styles. A representative selection of paintings was chosen for analysis of the

materials used in these paintings. One Indo-Iranian painting and one Mughal painting from tenth and eleventh century AH/ sixteenth and seventeenth century AD were selected. Different types of pigments were also collected from traditional artists for analytical identification. Samples of the paints and pigments were also collected from a beautiful artistic illuminated paint box belonging to Safavid period (tenth century AH/ sixteenth century AD) for scientific comparative study.

The materials used in the paintings including paper fibre, sizing materials, ground layer and pigments were analysed for materials identification. All the colours were sampled from each painting and paint palette under study. A complete record of the paper fibre, sizing materials, presence of ground layer and its nature, and pigment identification has been provided in Table 2-5. It also indicates the identification methods used in each case.

### Study Background Review

Indian and Persian paintings occupy an important place in the realm of Asian Art. In this regard, numerous articles have been published, books were compiled and attractive albums and reproductions were prepared by museums and art centres and so on. A quick glance over the bulk of these sources reveals that the majority of them have been put together from an art historian's point of view. Few sources mentioned have touched on the areas of painting techniques and the materials used.

There are very few serious works on the materials used in Persian and Indian miniatures. The earliest work that I have come across during my survey was published by A. P. Laurie in 1935.<sup>4</sup> The references and sources are somewhat neglected until 1980s. "A technical analysis of Indian painting materials" in 1985, is a work that appears after a gap of almost forty years.<sup>5</sup> As can be expected, this work emerges from a more scientific and technical

background. Three years later, a scholarly work by Elisabeth West FitzHugh entitled "Study of pigments on selected paintings from the Vever collection" appears in An Annotated and Illustrated Checklist of the Vever collection.<sup>6</sup> In this work, she has undertaken a scientific comparative pigment study of miniature paintings originating from Egypt, India, Iran, and Iraq. Six years later a work by Yves Porter entitled *Painters, Paintings and Books* was published.<sup>7</sup> It is a study of the Indo-Persian technical literature from the twelfth to the nineteenth century which treats the materials used in Persian paintings based on some of the Persian recipes; however the sources originated mostly from India. Scattered works, some of which are quite significant, were published in Iran, India, Pakistan, and Turkey, and elsewhere. They provide us with some information relating to the subject. However, most of these works emphasise the pigments and dyes used in different forms of art such as wall paintings, fabric paintings, oil paintings and the like. "Examination and Analysis of Wall Paintings" and "Identification of Natural Red Dyes in Old Indian Textiles" by O. P. Agrawal; "Scientific Investigations of materials Used in the 14<sup>th</sup> and 15<sup>th</sup> Century Cloth Paintings" by B. N. Tandon; "Conservation, Technical Studies of Scroll Paintings" by A. R. Shah; "Conservation of Indian Miniature Paintings, Prints and Water Colours" by S. Subbaraman; and many other works are among scholarly efforts in the field of pigments, dyes and conservation of the works of art.<sup>8</sup>

Some scholars did extensive research and laboratory work on specific pigments. Although such works have a background in pure chemistry, the results are valuable when it comes to the interdisciplinary field of conservation which requires as much artistic and aesthetic sense as it needs the support and minute scientific approach. Gettens, Khun, Plesters, FitzHugh, Schweppe,

Fig. 1. (left)  
Indo-Iranian  
miniature  
painting, 16<sup>th</sup>  
Century AD,  
Irān-e Bāstān  
Museum,  
checklist no.  
4555

Fig. 2. (right)  
Mughal  
miniature  
painting, 17<sup>th</sup>  
century AD,  
Irān-e Bāstān  
Museum,  
checklist no.  
4535



and Winterare the figures whom we come across more than once, while going through the published sources on the scientific studies of pigments.<sup>9</sup> The present study is based on oral traditional knowledge, historical literature of the fifteenth to nineteenth centuries Persian and Indian treatises as well as laboratory works from original samples.

### Oral and Historical Analysis Review

During the first and second stages, the oral interviews with the Iranian traditional masters and the historical survey from historical recipes, the author collected valuable oral information, historical documents and a number of treatises relating to the recipes for materials used in the art of the book and miniature painting that were documented during the Timurid, Safavid and Qajar periods. The author has only included a small number of these references within the present paper since this group of sources and references would require an entire

article to give them the attention that they deserve.

The preparation of support layers has been discussed in these sources in different subjects such as: paper making (*kāghaz sāzi*), dying paper (*gune kardan*), sizing (*āhār zadan*) and burnishing (*mohre kardan*). These topics have already been analysed historically and scientifically by the author and are published in international journals.<sup>10</sup>

A variety of supports mentioned in these oral and historical sources have already been identified and documented by the author. Briefly the supports that can be found in these two sources are: card board (*moqavvā*), decorated papers (marble paper, *abri* paper), ground works such as gold (*bum-e talā*), silver (*noghre-push*), gold powdered (*bum-e zarnegar*, *zarafshān*), green verdigris (*bum-e zangārī*), marcasite (*bum-e marghash*) and gold marcasite (*bum-e zarak*).

Preparation of the paint layer and the variety of pigments and dyes have also been discussed and documented by the author based

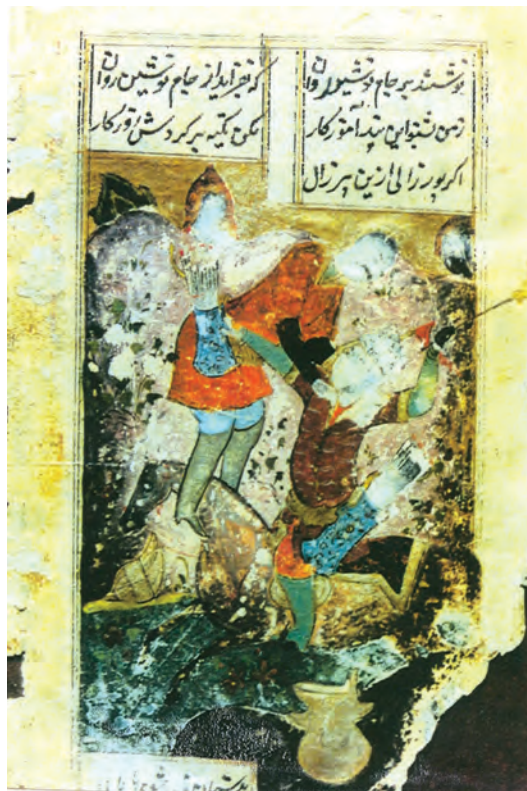


Fig. 3. (left) Safavid miniature painting, 16<sup>th</sup> century AD, private collection of M. Atiqi, checklist no. 13  
Fig. 4. (right, up) Safavid illuminated manuscript, 16<sup>th</sup> century AD, private collection of M. Atiqi, checklist no. 19  
Fig. 5. (right, down) Safavid paint box, 16<sup>th</sup> century AD, private collection of M. Tavosi, checklist no. 21

entirely on the oral and historical sources. The paint layer can be divided into the categories of opaque colours (*jesmi*), transparent colours (*ruhi*), resinous colours (*serishomi*). The pigments have also been divided into two categories: primary colours (*mofradāt*) and secondary colours (*morakkabāt*).

In these sources binding medium (*bast*) is also discussed and is divided into two sources: vegetable source (gum arabic or *samgh-e arabi*) and animal source (fish glue or *serishom-e māhi*).

The preparation of the brush is another subject that is thoroughly discussed by these sources. They identify hair from squirrel's tails and hair from cat's tails as the main sources for making brushes. From some of these sources one can find the technical application of the materials used in the art of the book making and miniature painting as well.

### Scientific Analysis Review

We find that several analytical methods have been used for the identification of different components of a miniature painting viz. support, pigments, sizing material, etc. For analyzing the materials of paintings, an important consideration is that the method should be non-destructive.

Twelve selected illuminated manuscripts, miniature paintings and paint boxes ranging from the sixteenth to late nineteenth century were collected. For comparative analytical research an Indo-Iranian miniature painting as well as two paintings belonging to the Mughal period were also collected and added to the group of samples as references (See figs. 1-5).

Table 1. Colour produced by iodine stains in case of historical paper fibres

Table 1  
Colour Produced by Iodine Stains in Case of Historical Paper Fibres

Stain	Linen	Cotton	Manila	Jute	Rag	Straw and Esparto	Japanese
C Stains			a. Raw: light greenish yellow b. Unbleached and bleached: yellowish gray to weak blue and medium gray	a. Unbleached, vivid yellowish orange b. Bleached : light yellow green	Moderate reddish range	a. raw: light yellow to weak greenish yellow b. Unbleached and bleached: light greenish grey to dark bluish grey	a. Gampi and mitsumata: light greenish yellow to light bluish green b. Kozo: pinkish grey
Herzberg Stain			a. Raw: Moderate yellow b. Unbleached and bleached: dark purplish gray to moderate purplish pink	a. Unbleached: moderate yellowish orange b. B. Bleached : Strong greenish yellow	Brilliant purplish pink to vivid red purple	a. Raw: light yellow b. Unbleached and bleached: light bluish gray to pale purplish blue and strong purplish pink	a. Gampi and mitsumata: light greenish yellow b. Kozo: pinish gray
Selleger Stain			a. Bleached: sclaret red		Red	a. Bleached: Blue	
Wilson Stain	Pink	Red				a. Raw cook: green b. Well cooked: blue c. Bleached: dark blue	

For the identification of the layers, the following were examined and analysed: 1) Support layer (paper fibre and sizing materials); 2) ground layer; and 3) Surface layer (pigments and dyes).

The analysis of materials was carried out at the Research Centre for Conservation Cultural Relics (RCCCR) in Iran, Institute of Standard Industrial Research of Iran (ISIRI), National Research Laboratory for Conservation of Cultural Property (NRLC) in India and the Indian Conservation Institute (INTACH).

## 1. Support Layer

### 1-1. Paper Fibre Historical Analysis

Iran was considered one of the most important centres of paper-making and it also acted as a bridge, transferring the art of paper-making from the East to the West. This art had become so popular throughout Iran that there were some cities in

which the entire population was engaged in paper-making. For instance, during the period of Yāqut (sixth and seventh Centuries AH) there was a city actually called Kāghaz-konān, which literally means city of paper producers, located between Marāḡhe and Zanjān that was very famous for producing quality paper. Interestingly, almost everyone in that city was engaged in paper production.<sup>11</sup> The quality of paper is described in *Rasm ol-khat*<sup>12</sup> and *Savād ol-khat*<sup>13</sup> in the sixteenth century as follows: "Good quality of paper is the one which is white, soft, crisp, smooth and even". Recommended papers are also mentioned in *Resale dar bayan-e tariq-e sākhtan-e morakkab va kaghaz-e alvān*, 16<sup>th</sup> AD, as follows:

Calligraphers should use good quality of paper. All types of paper from different places are experienced and the best are *samarqandi*, *baghdādi*, *dameshqī*, *mokhtari-ye amol*, *harir-e bangāle*

Table 2  
Paper Composition on selected paintings from Iran Bastan Museum Collection and Traditional Artists

Origin	Owner	Object	Date	Check list Number						Fibres					
					Lin	Cot	hem	Jut	Rag	Str	Bam	Man	Japanese Fibers		W.P.
													Gam Koz Mit		
Iran	Iran Bastan Museum	M	16th cent	4555	sm				s						
	Atiqi	I.M.	16th cent	11	s				s						
		I.M.	17th cent	12	sm	m	m		s						
		I.M.	17th cent	13	sm	m	m		s						
		I.M.	17th cent	14				sm	s						
		M	16th cent	15			m	sm							
		M	17th cent	16	sm		m		s						
		M	16th cent	18			m		m						
		M	16th cent	19	sm		m								
India	Iran Bastan Museum	M	17th cent	4535		sm	m								
	Atiqi	M	18th cent	17		sm	m								

**Key to Fibres:**

Lin - Linen    Str - Straw    Gam - Gampi    W.P. - Wood Pulp  
Jut - Jute    Bam - Bamboo    Koz - Kozo    Cot - Cotton  
Rag - Rag    Man - Manila    Mit - Mitsumata    hem - hemp

**Key to identification methods:**

m - appearance by transmitted light on a microscope slide  
observed by polarized light microscopy  
s - fibres identified by staining method



and *ostekhāri-e dameshqi*. These papers can be trusted but the other types of papers are mostly brittle, absorbent and not permanent.<sup>14</sup>

Briefly the variety of papers with good quality that are mentioned in these sources and other sources<sup>15</sup> can be listed as: *Dowlatabadi-ye baste*, *Samarqandi*, *Ostekhāri*, *Baghdādi*, *Dameshqi*, *Mokhtāri*, *Khatāyi*, *Hariri-ye samarqandi*, *Qanni*, *Adelshāhi*, *Ja'fari*, *Jeyhāni*, *Khānbāleq*, *Khorāsāni*, *Khonj*, *Dehqāni*, *Soleymāni*, *Sheytāni*, *Talhi*, *Feruni*, *Farangi*.

### Scientific Analysis

The identification of fibres was carried out by the application of stains and morphological methods.<sup>16</sup> The Herzberg stain was chosen for general analysis. The Wilson stains were used to confirm results

of the Herzberg stain and to differentiate between cotton and linen. In addition to staining method, observation of the morphology of the fibres was helpful in identification of paper fibres.

A large collection of authentic fibres was prepared for comparison with the samples. The optical appearance of the fibres, on a microscope slide, was observed in plane polarized light (polarized microscope, Games swift, England, MP 3502) and wild zoom stereomicroscope (wild M 8200 m stereo microscope with low inclined trinocular tube and with wild 35 mm magazine).

The colours produced by iodine stains in the case of historical paper fibres are shown in table 1. Table 2 provides a complete record of the fibres found and indicated

Table 2. Paper comparison on Safavid, Indo-Iranian and Mughal miniature paintings. Fig. 6. (right) Morphology of paper leaf, Indo-Iranian miniature painting, 16<sup>th</sup> AD, Irān-e Bāstān Museum, Checklist no. 4555. Fig. 7. (left) Morphology of paper leaf, Mughal miniature painting, 17<sup>th</sup> AD, Irān-e Bāstān Museum, checklist no. 4535

Table 3  
Sizing Materials on Selected Paintings collected from Iran Bastan Museum Collection and Traditional Artists

Origin	Owner	Object	Date	Check List Number	Sta	Fis	gum	Isp	Swe	Ric	Gra	Cue	Sug	Myr	tra
IRAN	Iran Bastan Museum	M	16th c.	4555	sf										
	Atiqi	I.M.	16th c.	11								f			f
	"	I.M.	17th c.	12								f			
	"	I.M.	17th c.	13								f			
	"	I.M.	17th c.	14								f			
	"	M	16th c.	15								f			
	"	M	16th c.	16								f			
	"	M	16th c.	18								f			
	"	M	16th c.	19								f			
INDIA	Iran Bastan Museum	M	17th c.	4535	sf										
	Atiqi	M	18th c.	17	sf										

**Key to sizings:**

Sta - starch  
Fis - Fish glue  
Gum - Gum arabic  
Isp - Ispagol  
Swe - Sweet melon  
Ric - Rice mucilage  
Gra - Grape Syrup

**Key to object**

I.M - illuminated manuscript  
M - Miniature  
P.B - Paint Box  
P.P - Paint Palette  
Tra - tragant (katira)

**Key to identification methods:**

S - determination of starch by staining the paper with iodinepotassium iodide solution  
f - identification of sizing materials in the sample is obtained by comparing the infra red spectrum with reference spectra or by recognizing specific bands

Cuc - Cucumber's Seeds Sug - Sugar Syrup Myr - Myrtle Juice Tra - Tragant (katira)

Table 3.  
Identification of  
Sizing materials  
on Safavid,  
Indo-Iranian  
and Mughal  
miniature  
paintings

identification methods used in each case.

Our investigation revealed that the raw materials used for the manufacture of paper in India were mostly cotton and hemp, whereas in Iran paper was invariably made from fibres of flax in the form of linen rags, with hemp fibres added on occasion (See figs. 6 and 7).

## 1-2. Sizing Material Historical Analysis

According to Persian historic treatises, a variety of sizing materials were used during the Timurid to Qajar periods, and they have already been identified and published by the author.<sup>17</sup> Sizing materials from proteinaceous materials including animal glue; starches from rice or wheat; vegetable gums; mucilage of plants and seeds; fruits and sugar were mentioned. The sizes that the author has identified from the historical sources are: starches; wheat (*neshāste-ye gandom*) and rice (*neshāste-ye berenj*), plant mucilage; rice (*lo'āb-e berenj*), fleawort seed (*aspghul*, *esfarze*, *quitona*), mucilage

of marshmallow (*lo'āb-e khatmi*), cucumber seeds (*lo'āb-e tokhm-e khiyār*), Fruit juices/syrups; grape syrup (*shire-ye angur*), juice of sweet melon (*āb-e kharboze*), animal glue; fish glue (*serishom-e māhi*), vegetable glue; gum arabic (*samq-e 'arabi*), kind of vegetable glue (*serish*).

The sizes were not only used in pure form but also occasionally depending on the types of paper, mixed sizes were also practiced. In *Resale dar bayan-e khat va morakkab* it is advised:

If a paper has deep turquoise colour and it is difficult to write on, the advice is to apply either sweet melon juice (*āb-e karboze*), or syrup of Egyptian rock sugar (*āb-e nabāt-e mesri*) or myrtle extract (*āb-e mord*) with mucilage of fleawort seed (*aspghul*) and mucilage of oil free cooked rice (*lo'āb-e berenj*). All these materials make paper strong and if paper is burnished it becomes smooth like a mirror.<sup>18</sup>

## Scientific Analysis

The scientific analysis that has been carried out to identify the

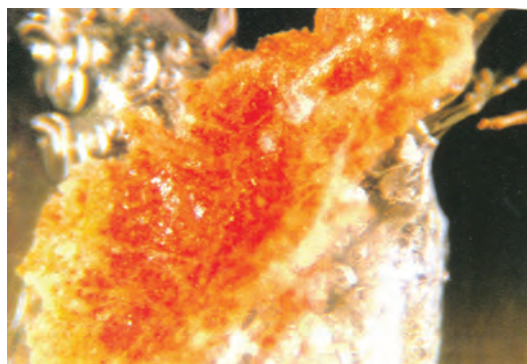


Fig. 8. (right) Microscopic examination of paint, Safavid miniature painting, ground layer was not observed, checklist no. 15 (40x magnified)  
Fig. 9. (left) Cross section of paint, Mughal miniature painting, ground layer was observed, checklist no. 17 (40x magnified)

sizing materials used in Persian paper has already been identified and published by the author.<sup>19</sup> Sizing materials were identified by staining<sup>20</sup> and FT-IR<sup>21</sup> spectrometer analysis. Starch was also detected in paper by the formation of the characteristic blue colour when a dilute aqueous solution of iodine-potassium iodide was added.<sup>22</sup> Large collections of sizing materials mentioned above were prepared based on our historical survey from historical treatises, for comparison with the samples by FT-IR spectrometer analysis.<sup>23</sup> Tragacanth (*katirā*), though it was not mentioned in historic treatises under study, was added as our analytical sample since it was recorded in scientific reports. FT-IR (Fourier Transform Infra-Red) spectrometer was carried out with a Nicolet, Model 510 P instrument provided with a microscope attachment. Sample preparations were carried out by mixing KBr, and the unprepared sample in the ratio of 100:1. Identification of the sizing materials in the sample is obtained by comparing the infrared spectrum with reference spectra or by recognizing specific bands.

Table 3 provides a complete record of the sizing materials found and indicates identification methods used in each case.

Unlike the Indians who used limited sizing materials to improve the mechanical strength and to smoothen the surface, Iranians used various materials in the sizing process. According to our investigation cucumber seeds were

extensively used compared to other sizing materials.

## 2. Presence of Ground Layer Historical Analysis

According to Indian sources the next layer after preparing the support layer was sizing and burnishing, a layer called the ground layer. In Indian Mughal miniature painting before applying paint on the paper, the sketch was prepared by the master artist on the smooth surface of the paper in light blue or reddish-brown ink. This primary sketch was drawn in soft lines suggesting only the outlines of the figures. These were later corrected and bold, accurate, hard lines were drawn. A coat of white pigment known as ground layer was applied to obliterate the incorrect lines. In Persian historic treatises we did not find any evidence that the ground layer was applied on the support layer before the paint surface layer.

## Scientific Analysis

The presence of a ground layer was detected by microscopic examination.<sup>24</sup> Preparing cross sections was only possible for one of the paintings selected. Stereomicroscopy was carried out with Model wild M8 zoom stereo provided with a camera attachment. Identification of material used in the ground layer of Indian miniature painting was carried out by FT-IR (Fourier Transform infra-red) spectrometer analysis with a Nicolet, Model 510 P instrument. Identification of the material on

(up to down)

Fig. 10.

Microscopic examination, part of Mughal miniature painting, checklist no. 4535, ground layer was observed (6x magnified)

Fig. 11.

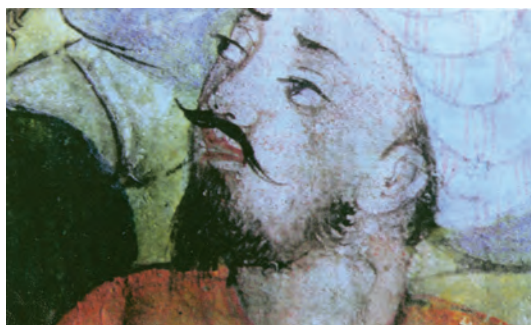
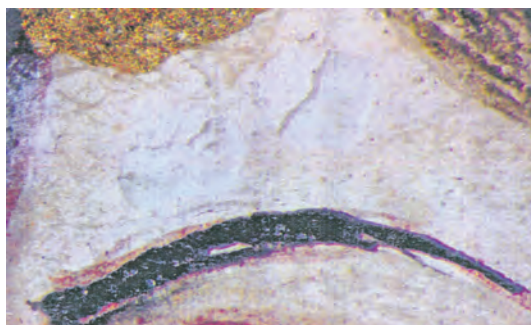
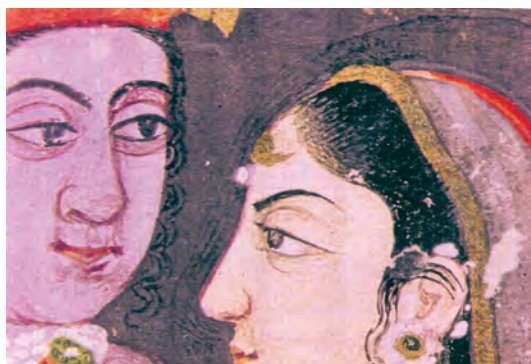
Microscopic examination, part of Mughal miniature painting, checklist no. 4535, ground layer was observed, flaking off the paint due to presence of ground layer (6x magnified)

Fig. 12.

Microscopic examination, Indo-Iranian miniature painting, checklist no. 4555, ground layer was not observed (6x magnified)

Fig. 13.

Microscopic examination, Indo-Iranian miniature painting, checklist no. 4555, ground layer was not observed (12x magnified)



the ground layer is obtained by comparing the infrared spectrum with reference spectra or recognizing specific bands. Table 4 provides the record for the presence of ground

layer found and indicates the materials identified.

In Indian paintings, a ground layer was almost always present while in Iranian paintings, the ground layer was seldom applied. This gives an explanation of the fact that the flaking of paint is very much more evident in Indian miniatures than in Persian miniatures (See figs 8-13).

### 3. Pigment

#### Historical Analysis

According to classical treatises the colours were classified in two categories: Primary (*mofradāt*) and secondary (*morakkabāt*).

According to these sources primary colours (*mofradāt*) are white (lead white/ *sefidāb*, tin white/ *esfedāj-e hal*), yellow (orpiment/ *zarnikh*, rhubarb/ *rivand*), red (vermillion/ *shanjarf*, red lead/ *soranj*, red orpiment/ *zarnikh-e sorkh*, safflower/ *mo'asfar*, carmine *kerm-e-qermez*, *qermez-dāne*, lac lak, brazil wood/ *baqam*, red and brown earth/ *okhr va omra*), green (verdigris/ *zangār*), blue (lapis lazuli/ *natural lajevārd* and artificial ultramarine/ *lajevārd amali*, indigo/ *nil*), black (lamp black/ *dude*) and metallic (gold/ *talā*, silver/ *noqre*, brass/ *berenj* and copper/ *mes*, mica/ *talq*).

On the other hand the secondary colours (*morakkabāt*) are face colour (red lead + white), elephant colour (green or blue + lamp black), light brown (yellow ochre + black), deep green (lamp black + indigo and rhubarb), purple (lapis lazuli + vermillion) and turquoise (ultramarine + green).

Referring to historic sources we can identify different techniques in the making of pigments and dyes and the types of binding medium advised by the masters for particular paint and purposes. For example Syerafi in *Golzār-e safā* explains the technique for making lead white (*sefidāb-e sheykh*) as follows:

Take some pieces of lead and place it in a big vessel. Heat it on fire till the lead melts. During the whole process, cover the vessel. After

Table 4  
Presence of Ground-layer on Selected Painting Collected from Iran Bastan Collection and Traditional Artists

Origin	Owner	Date	Check list Number	Ground Layer was observed			Ground layer was not observed
				Gyp	Ldw	Chk	
IRAN	Iran Bastan Museum	16th c.	4555				m
	Atiqi	16th c.	15				m
		17th c.	16				m
		16th c.	18				m
		16th c.	19				m
INDIA	Iran Bastan Museum	17th c.	4535		mf		
	Atiqi	18th c.	17		mf		

**Key to the nature of ground layer:**

Gyp - Gypsum (calcium sulphate)

Ldw - Lead white (lead carbonate)

Chk - Chalk (calcium carbonate)

**Key to identification methods:**

m - microscopic examination

f - FT-IR examination of coating

the lead is melted wash it with vinegar (serkeh) and sal-ammoniac (naushadur). When it is rubbed and pulverized finely, wash it thoroughly till you get pure safeedab. In this way lead white is produced.<sup>25</sup>

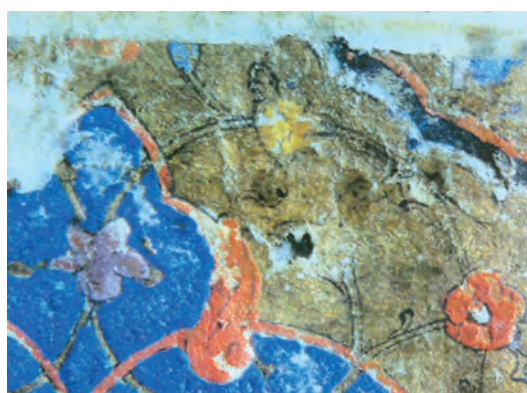
Al-Kashfi explains the types of binding medium used with lead white as follows:

Moisten sefidab with water. Pass it through a clean fine cloth. If it is required to use it on paper, add gum-arabic. For other purposes mix it with egg-white.<sup>26</sup>

### Scientific Analysis

Pigment identification was carried out in different techniques as follows: microscopical analysis, microchemical analysis, FT-IR (Fourier transition infra red), XRD (x-ray diffraction), UV (ultra violet lamp).

Table 5 provides a complete record of the pigments collected from traditional artists and selected paintings from Irān-e Bāstān Museum and indicates the identification method used in each case. Figure 14 shows part of Safavid illuminated manuscript belonging to 17<sup>th</sup> century of check list no.12 that its pigment identification was also under investigation. Table 6 shows the pigments identified from selected Indian and Persian miniature paintings from the Vever Collection. By comparing tables 5 and 6, it can be noted that the pigments used



on the selected paintings come from a variety of sources. Some are artificially prepared inorganic materials like verdigris. Some are naturally occurring minerals, which were ground to produce powdered pigments, such as ultramarine. Others, such as cochineal, are organic pigments or dyes from animal or plant sources. The palette of the paintings is wide. Many of the colours were produced by a single pigment; others are a mixture of two or more colorants.

Indian yellow,<sup>27</sup> common on Indian paintings, was not found on Persian paintings. Orpiment (*zarnikh*) and rhubarb (*rivand*), are much more widely used on Persian paintings than on those of India. Figure 15 shows the microscopic image of Indian yellow found in Mughal miniature painting of checklist no. 4535.

Table 4.  
Presence of ground layer on Safavid, Indo-Iranian and Mughal miniature paintings  
Fig. 14. Part of Safavid illuminated manuscript, 17<sup>th</sup> century AD, private collection of M. Atiqi, checklist no.12

Table 5  
Pigment collected from Traditional Artists and Selected paintings from Iran Bastan Museum

Pigment collected from Traditional Artists and Selected paintings from Iran Bastan Museum																											
Origin	Owner	Object	Date	Check List Number	Pigments																						
					White			Red			Yellow			Green			Blue		Earths		Black		Metallics			Others	
					Ldw	Cha	Tiw	Ver	Rld	Org	Orp	Ind	Rub	Cug	Mal	Ter	Ult	Ind	Rd	Br	Car	Iro	Org	Sil	Gld		
IRAN	Iran Bastan Museum	M	16th c.	4555	f			m	m		m		f				fc	m	m	mc	m					m	
	Atiqi	I.M.	16th c.	11	m			m	m								fm				m					m	
	"	I.M.	17th c.	12	m			m	m								m									m	
	"	I.M.	17th c.	13	m			m			m				mfc			m			m	m					
	"	I.M.	17th c.	14	m			m										m				m				m	
	"	M	16th c.	15					m													m					
	"	M	17th c.	16	f			m	m					mf	c			f			m	m				m	
	"	M	16th c.	18	mfc			cm	cm	f	m			f	mfc			mfc			c						Saffron
	"	M	16th c.	19	fc			c		m	c			f			cf			c						Saffron	
	Tavocsi	P.B.	16th c.	21	f				c	cf	c		f	cf			f	f	c	c			fc			Saffron	
INDIA	Iran Bastan Museum	M	17th c.	4535	mf			mc	mc	mf	f	mfu		fc			fm	m		mc	m				m	langite	
	Atiqi	M	16th c.	17						f		u		fc			f				m						green atacamite

#### Key to Pigments:

Car= Carbon  
Cug= Copper green  
Gam= Rubarb  
Gld= Gold  
Idg= Indigo  
Ind= Indian yellow

#### Key to subjects

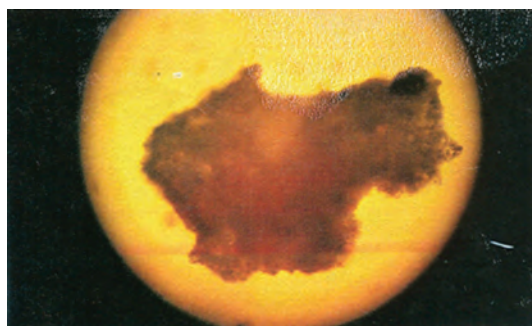
I.M - Illuminated manuscript  
M - Miniature  
P.B - Paint Box  
P.P - Paint Palette

#### Key to identification methods:

m= appearance by transmitted light on a microscopic slide observed by polarized light microscopy  
c= elements identified and solubility  
x= Crystalline structure by x-ray powder diffraction  
u= fluores cos in long-wave ultraviolet light

Ldw= Lead white Mal= malachite Org= Organicred Orp= Orpiment Rd Br= Red-Brown Rld= Red lead Cha= Chalk Tiw= Tin white Org= Organiz black

Table 5. Pigment identification on Safavid, Indo-Iranian and Mughal paintings Fig. 15. Microscopical analysis of paint, Mughal miniature painting, 17<sup>th</sup> Century AD, checklist no. 4535



The greens are said to be malachite or verdigris, but the yellow-blue mixture described by early writers turns out to be much more common. Orpiment-indigo and ultramarine-rhubarb (*rivand*) mixture used to produce green are much more widely used on Persian paintings than on those of India.

E. FitzHugh<sup>28</sup> has indicated that terre verte was not identified on any painting in the series, nor has it been found on other Indian paintings.<sup>29</sup> In the series which we examined, terre verte, the natural green stone (*sabz-e silu*), was not identified either. According to our investigation, *silu*, a term used by the Persian artists from describing earth green, is mainly a mixture of blue and yellow, a deep green colour shade however to make a definite statement on this fact it needs more further study.

By comparing tables 5 and 6 it can be noted that verdigris appears to be more common on Persian than on Indian paintings. According to previous extensive investigation done by the author based on historical survey and analytical research, it has been discovered that *Zangār* was used in Iran as a green pigment and mixed with saffron as an inhibitor to prevent the destructive mechanism of verdigris.<sup>30</sup> In India, on the other hand, there is no evidence of mixing saffron with verdigris or with any other pigments.

In many cases historical descriptions based on historical treatises and documents correlate well with what has been found on the paintings; the description, however, mentions some pigments that were not found in this series of paintings. Figures 16 and 17 shows two samples of microscopic images of pigments found in paint palette checklist no. 51 belonging to 16<sup>th</sup> century of Safavid period.

## Conclusion

As is expected, the materials and techniques used in early Indo-Iranian paintings were similar to those of the Safavid tradition. However, according to our investigation it seems that within the space of one

Table 6  
Pigments on Selected Paintings from the Vever Collection

Pigments on Selected Paintings from the Vever Collection																
Origin	Date	Check List Number	Pigments													
			White	Red			Yellow		Green		Blue		Earths	Black		Others
			Ldw	Ver	Rld	Org	Orp	Ind	Cug	Mal	Ult	Idg	RdBr	Car	Sil	
IRAN	ca. 1335-40	69	mx	mc	m	m	m		mc		m	mc	m	m	x	azurite
	ca. 1335-40	70	m	mcx	m	m	m				m	mc	mc	m		
	1417-18	48	mcsx	m	m	m	m		mc		m	mc		m	x	
	ca. 1505	248	mc	mc	m	m	m		mcx		mx	mc	mc	m	x	
	ca. 1590-1600	124	mcsx	m	m	m	m		ms		m	mc		m		
	ca. 1590-1600	146	mcx	m	m	m	m				m	mc	mc	m		
Bukhara	ca. 1600	362	mx	mx	m					mx	mc	m	m	x		
Gilan	1493-94	105	mcx	mc	m	m	mx		mcs		mx	mc		m		
Herat	ca. 1425	165	mx	mcx	m	m	mx				mx	mc		x		
Herat	ca. 1600	157	mcsx	mc	m	m	m		mc		m			m	x	
Khurasan	ca. 1575	189	mx	m	m	m	m		mcx		mx		mc	m		
Qazwin	ca. 1590-1600	211	mcsx	m	m	m	m		ms		mx			m	x	
Qazwin	ca. 1590-1600	275	mx		m	m	mx				m	mc	mc		x	
Shiraz	1341	75	mx	mx	m	m									x	
Shiraz	1341	83														
Shiraz	ca. 1440	97	mx	m	m	m	mx				mx	mc		m	x	
Shiraz	ca. 1560	117	mcsx	mc	m	m	mx		mcs		m	mc	mc		x	
Tabriz	ca. 1525	250	mcx	mcx	m	m	mx		mx	mx	m	mc	mc	m	x	
Tabriz	1550	169	mx	m	m	m	m				m	mc		m	x	
INDIA	1450	197		m	m	m	m				mx	m	mc		m	
	ca. 1562-77	38	mx	mc	m		m				m	mx	mc	mc	m	
	1589	60	mcx	m	m	m	mx	mu		m	m	m	mc	mc	m	
	17th c.	345	mcsx	mc	m	m		mu	mcs	mx	mx			mc	m	
	ca. 1605	367	m		m	m				mx	m	mx				
	1629-30	336	mcx	m	m	m		mu		m	mx	mx		mc	m	
	ca. 1635	377	mcx	mcx	m	m		mu		m	m					
	ca. 1700	416	mx	mc		m		mu					mc		m	
	19th c.	425	mcx		m	m		mu					mc		m	
	late 19th c.	47	mcx		m	m		mu					mc	mc		
	ca. 1900	403	mcx	mc	m	m		mu			m	m		mc	m	

Key to Pigments:

Car= Carbon  
Cug= Copper green  
Gam= Rubarb  
Sil= Silver  
Idg= Indigo  
Ind= Indian yellow

Key to Id: Key to Identification methods:

m= appearance by transmitted light on a microscopic slide observed by polarized light microscopy  
c= elements identified and solubility  
x= Crystalline structure by x-ray powder diffraction  
u= fluoresces in long-wave ultraviolet light

Ldw= Lead white Mal= malachite Org= Organic red Orp= Orpiment Rd Br= Red-Brown Rld= Red lead Ver= Vermillion Ult= Ultramarine

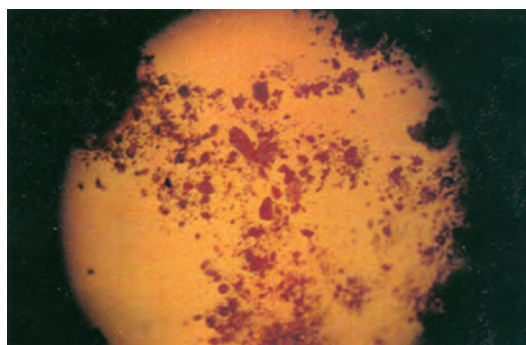


Table 6. Pigment identification on selected paintings from the Vever collection  
Fig. 16. (right) Microscopical analysis of paint, Safavid paint palette, 16<sup>th</sup> Century AD, checklist no. 51  
Fig. 17. (left) Microscopical analysis of paint, Safavid paint palette, 16<sup>th</sup> Century AD, Checklist no. 51

century the materials and techniques changed and found their own new identity, integrating native materials and techniques in different layers of miniature paintings.

From the support layer we found the different sources of cellulose fibre based on the availability of the materials. According to our investigation the raw materials used for the manufacture of paper in India based on our sample from seventeenth century Mughal paintings were mostly cotton and hemp whereas the paper used in our early Indo-Iranian painting and

sixteenth century Safavid painting paper was invariably made from fibres of flax in the form of linen rags, with hemp fibres added on occasion.

In the case of sizing materials, unlike the Indians who used limited sizing materials namely starch paste to improve the mechanical strength and to smoothen the surface, Iranians during the Safavid period used various materials for the sizing process. According to our investigation cucumber seeds were extensively used comparing to other sizing materials.

In the next layer on Mughal paintings, a ground layer was almost always present while in Safavid and early Indo-Iranian paintings, the ground layer was seldom applied. This explains the fact that the flaking of paint is more evident in Indian miniatures than in Persian miniatures.

In the case of the final layer, through our laboratory research we found that some of the pigments and dyes that were common in the Safavid and early Indo-Iranian paintings were not used and were not practiced in Mughal painting, such as the mixing of saffron as an inhibitor to prevent the destructive effect of verdigris. This explains why most of green verdigris pigments used in Mughal miniature paintings are damaged by the destructive effect of verdigris whereas the green verdigris used in Safavid miniature paintings are in good condition due to the buffering property of saffron and its preventive measure. On the other hand Indian yellow, common on Indian paintings, was not found at all on Persian ones. Orpiment (*zarnikh*) and rhubarb (*rivand*), are much more widely used on Safavid paintings than on those of Mughal. The greens have been said to be malachite or verdigris, but the yellow-blue mixture described by early writers turns out to be much more common. Orpiment-indigo and ultramarine-rhubarb (*rivand*) mixture used to produce green are much more widely used on Safavid paintings than on those of Mughal. □

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## Notes

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6. FitzHugh, E. W. "Study of Pigments from the Vever Collection".
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