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# Art historical and scientific controversies about four easel paintings attributed to Kamal al-Molk, the renowned nineteenth-twentieth century Persian painter

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## Abstract

Pigments on four easel paintings signed by Mohammad Ghaffari (latter Kamal al-Molk), the renowned Persian painter lived from the mid-nineteenth to the mid-twentieth century, kept at the Astan-e Qods-e Razavi Museum (AQRM) in Mashhad, Iran, were identified by micro-X-ray fluorescence ( $\mu$ -XRF), scanning electron microscopy—energy dispersive X-ray spectrometry (SEM-EDS) and micro-Raman spectroscopy ( $\mu$ -Raman). Apart from chrome yellow, green chromium oxide and red ochre, four blue pigments including Prussian blue, artificial ultramarine blue, azurite, blue phthalocyanine PB:16 and seven white pigments including rutile, huntite, lead white, baryte, chalk, gypsum and zinc white were identified on the paintings. Based on the occurrence of rutile and blue phthalocyanine PB:16 and the fact that the signature of the paintings suggests 1875 as the date of executing the paintings, several hypotheses were argued to discuss the latter interventions and the authenticity of the works. Discussions on the birth date and other important milestones of Kamal al-Molk's life accordingly posed serious questions on the authenticity of these paintings.

**Keywords** Kamal al-Molk, Mohammad Ghaffari, Authenticity, Pigment analysis

## Introduction

Thanks to recent advances in scientific methods of investigating works of art, art authentication has gone beyond art historical discussions. Scientific methods, as important aid for art historians, are being developed to facilitate authenticating suspected objects of arts and archaeology [1]. Some of these scientific methods are based on absolute dating of artefacts such as radiocarbon dating [2, 3]. These methods provide unrivaled data which offer solid responses to the questions of authenticity of artworks. However, absolute methods of dating are

not widely available and cannot be accessed in a regular base. In addition, when the support of the painting is dated by absolute methods, there is always a chance that an old support has been used for executing the fake arts. Therefore, a relative dating relying upon the pigments found in a painted art may be used as source of information for authenticating works of art. Some pigments are popular in a certain period of time and some modern ones are first manufactured in a specific date. The occurrence of well-dated pigments thus can be used to depict a clearer image of dating of painted arts. Several examples of using this approach show its efficacy in discerning fake from authentic objects [4]. While this approach has been widely used to shed light on the history of works of art with suspected origin [5–8], scattered attempts have also conducted to elucidate the authenticity of Persian

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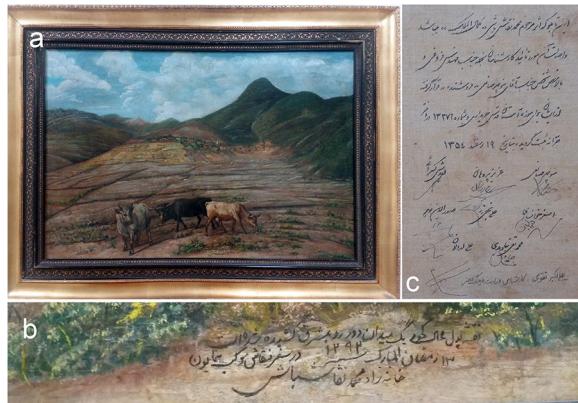
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painted works by scientific methods relying upon the pigments identified on these manuscripts [9–11].

The authentication of Persian works of art and archaeology became matter of debate in the late nineteenth and early twentieth century, when a large number of Persian archaeological objects and works of art was circulated in the western market and, museums and collections sought to purchase them [12]. Attention to the Persian art was in fact triggered in the early twentieth century when exhibitions were held in the US and Europe to introduce the relatively unknown Persian arts and culture to the western world. Soon after, controversies raised about the authenticity of some of these objects [13]. Amongst the controversial art and archaeological objects, the Islamic illuminated manuscripts and painted ceramics were of high demand [14]. The authentication of these works of art and archaeology has been mainly based on art historical arguments that art connoisseurs were building relying upon their knowledge of Persian history and art.

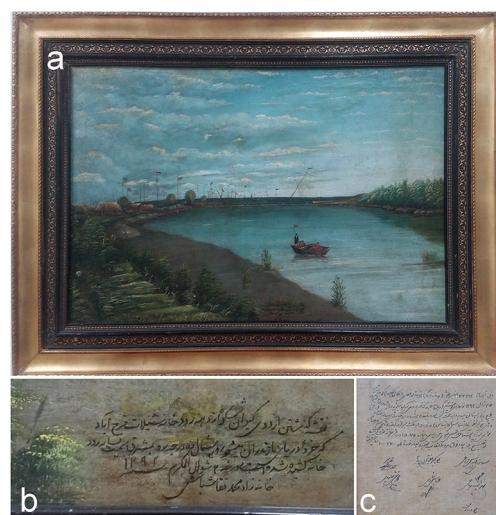
### Research aim

In the late nineteenth and early twentieth century, while the western world had begun to pay attention to the near eastern art, Iranian artists— at least in part— were seeking to learn the European classic styles of arts. This was due to the connections that Iranian elites had established with the West and the fact that the Iranians had begun practicing western-style democracy through the Constitutional Revolution. The current article aims to study four easel paintings signed by a renowned Persian painter, Mohammad Ghaffari, who adopted the western classic style of paintings in the verge of the twentieth century, when the Persian arts were becoming more popular and art dealers were collecting Persian art objects and circulating them not only in the western world but also across the country. The paintings under question are currently preserved



**Fig. 1** Image of **a** Kojur painting together with its **b** front and **c** retro inscriptions

at the Astan-e Qods-e Razavi Museum (AQRM) in Mashhad are namely “the picture of Kojur” (hereafter Kojur) (Fig. 1a), “the picture of royal excursion while passing though the opening of the Shilat-e Farahabad river” (hereafter Farahabad) (Fig. 2a), “the picture of Safiabad lagoon, Ashraf of Mazandaran” (hereafter Safiabad) (Fig. 3a) and “the picture of the Tajan’s bridge” (hereafter Tajan) (Fig. 4a). The following content is an attempt to identify the limited number of samples collected from these paintings using scanning electron microscopy—energy dispersive X-ray spectrometry (SEM-EDS), micro-X-ray fluorescence ( $\mu$ -XRF) and micro-Raman spectroscopy ( $\mu$ -Raman), and to discuss the results in light of some historical events in order to shed light on the authenticity of the paintings.



**Fig. 2** Image of **a** Farahabad painting together with its **b** front and **c** retro inscriptions



**Fig. 3** Image of **a** Safiabad painting together with its **b** front (note the self-portrait of the painter) and **c** retro inscriptions



**Fig. 4** Image of **a** Tajan painting together with its **b** front inscription and **c** the portrait of the painter on the painting

## Historical background

Mohammad Ghaffari (latter entitled Kamal al-Molk) is one of the most praised Persian painters who lived from ca. mid-nineteenth up to ca. mid-twentieth century. Perhaps, Kamal al-Molk is the most controversial Persian painter whose works received polarised comments. From one hand, he is considered the father of modern Persian painting, who adopted naturalistic style of painting in addition to the fact that he commenced systematic education of painting by establishing the first methodical system for teaching arts (i.e., Academy of Fine Arts), which eventually had a great impact on Iran modern style of Painting [15]. On the other hand, Kamal al-Molk is criticised for imitating the naturalistic style of paintings when the European painters were in the verge of seeking new styles of painting. Criticism is also extended to his incorrect use of colour in oil paintings along with the wrong adoption of perspective rules [16]. Regardless of these polarised comments, Kamal al-Molk is often considered to be the apex of an art style which commenced in the seventeenth century in Iran as a result of three main reasons: (1) the growing contact of the Iranians with the Europeans through commercial and diplomatic missions, (2) close connection of the Armenian community in New Julfa of Isfahan with European paintings and (3) the new western-oriented art which was emerging in India. These kind of associations resulted in the creation of a Euro-Persian style which continued up to the nineteenth-twentieth century and culminated with Abu al-Hasan Ghaffari (Kamal al-Molk's uncle), Mozayyen al-Doleh (the first and only teacher of Kamal al-Molk) and Kamal al-Molk [17].

There are some milestones in the life of Kamal al-Molk which have a key role in the further discussions of this article. First, the birth date of Kamal al-Molk is a matter of controversy. This is mainly because Kamal al-Molk himself was uncertain about his exact date of birth. It has been widely noted that Mohammad Ghaffari was born in 1264/1848 (the dates are given in A.H./A.D. throughout this article) [15, 18–20]. In his conversation with Mohammad-Ali Foroughi, however, he mentions that he was born during one of the campaigns of Naser al-Din Shah (Naser al-Din Shah was the king of Persia from 1848 to 1896) in Soltaniyeh (Naser al-Din Shah has had two campaigns in Soltaniyeh in 1275/1858-9 and 1279/1862-3) [21]. Therefore, based on several well-known events occurred in his life, Ashraf and Diba [17], argue convincingly that Kamal al-Molk must have been born ca. 1275/1859. As another evidence, Iran Ghaffari, the nephew of Kamal al-Molk, mentions that he was married in 1301/1884, when he was 25 years old [22]. This points, in line with the Ashraf and Diba's notion, to ca. 1275/1859. As another evidence, Kamal al-Molk was 12–15 years old when he entered Dar al-Fonun (a college founded by Amir Kabir in 1268/1851) [15, 18] and studied there for 8 years [23]. Adding these 15 and 8 years to 1275/1859, it sums up to 1298/1880, which fits well with the date he was entered the court (Table 1). For these reasons, in line with the Ashraf and Diba's assumption, we argue that Kamal al-Molk should have been born in ca. 1275/1859.

Mohammad Ghaffari received two titles from Naser al-Din Shah, i.e., 'naqqashbashi' (the chief court painter) and 'Kamal al-Molk' (literally means 'perfection of the Realm'). While there is no doubt in the date of receiving the Kamal al-Molk title (it was granted by the Shah in 1311/1894 based on a document a copy of which published by Soheyli Khan-sari [20]), the 'naqqashbashi' title has been argued to have been granted from 1298 to 1301 (see Table 1). In fact, the Naser al-Din Shah's visit from the Dar al-Fonun, which ended up hiring Mohammad Ghaffari as 'naqqashbashi', could not have been occurred before 1298/1880 since the Shah's visit from the Dar al-Fonun happened when Naser al-Din Shah observed the portrait of his deceased uncle (E'tezad al-Saltaneh) painted by Mohammad Ghaffari. This painting was a copy of E'tezad al-Saltaneh's photograph presented in the final ceremony of the Dar al-Fonun. Since E'tezad al-Saltaneh died in 1298/1880 [24], it is not likely that Mohammad Ghaffari has been entitled naqqashbashi prior to 1298/1880. Another piece of evidence is the letter that Abu al-Hasan Foroughi sends to Vezarat-e Maliyeh (The Ministry of Finance) in December 1926/January 1927 in order to remind the decrees of the Shah for establishing the retirement's stipend of Kamal

**Table 1** Important dates (A.H./A.D.) in the life of Mohammad Ghaffari, Kamal al-Molk

Reference	Birth	Age in entering the Dar al-Fonun	Summoned to the Court	titled naqqashbashi in	titled Kamal al-Mulk in	Moved to Europe	Returned from Europe
Sohayli Khansari [20]	1264/1848	12		1300/1883	1311/1894	1315/1897	1319/1901
Forughi [21]	1280/1863	Adolescent	Before 1298/1881	–	–	More than 2 years	
Dehbashi [62]	1264/1848	13	1298/1881	1305/1888	1310/1892	1314/1896	1319/1901
Ghani [23]	The beginning of the Nasir al-Din Shah reign	–	After 1298/1881	–	–	From 1314/1896 for more than 3 years	
Golbon [18]	1264/1848	15		1305-6/1888-9	1310/1892	1314/1896	1318/1905
Pakbaz [22]	1261-4/1845-8	–	After 1298/1881	4 years after entering the court	1310/1892	1314/1896	1318/1900
Ashtiani [15]	1264/1848	15	After 1298/1881	–	1310/1892	1314/1896	1318/1900
Ashraf and Diba [17]	1275/1859	12	1297-8/1880-1	1300/1883	1312/1894	1315/1898	1319/1900

The date of foundation the Academy of Fine Arts, Kamal al-Mulk's marriage and his death are agreed in all sources to be in 1329/1950, 1301/1922 and 1359/1980, respectively. Also, most sources agree that Kamal al-Mulk moved to Iraq in 1321/1942 and returned Iran in 1323/1944

al-Molk [20]. In this letter, Abu al-Hasan Forughi clearly mentions the decree of the Shah issued in 1300/1883 entitling Mohammad Ghaffari as 'naqqashbashi' of the court.

Kamal al-Molk was married in 1301/1884 and moved to Europe in 1315/1898 where he was influenced by European painters such as Titian, Rembrandt and Rafael. He returned to Iran in 1319/1901 and after a series of events, moved to Iraq in 1321/1903 and stayed for 2 years. He returned to Iran in 1323/1905 and established Madreseh-ye Sanyae' Mostazafeh (The Academy of Fine Arts) in 1329/1911. Upon some conflicts, he was retired and moved to Hosseyn Abad village, near Nishapur, in 1347/1928, where he died in 1359/1940 [20]. Table 1 presents the summary of important dates in the life of Kamal al-Molk.

Several attempts have been made in order to list the works of Kamal al-Molk. Karimzadeh Tabrizi [25] and Soheyli Khansari [20] list 102 and 75 paintings painted by Kamal al-Molk, respectively. Ashraf and Diba [17] also provide a list of 122 paintings of Kamal al-Molk many of which, however, have not been mentioned by Kamal al-Molk himself (he recalls 73 paintings in his interview with Ghani) [23]. The works of Kamal al-Molk are often categorised in three main groups; the first group includes those paintings executed before his move to Europe and the second group comprises of the paintings executed over his stay in Europe. The third group of the Kamal al-Molk's paintings is consisted of the paintings completed upon his return from Europe up to his final years of life.

## Materials and method

### The paintings

All the paintings under study are 100×70 cm in size. The paintings are executed on canvas and nailed on wooden stretcher. The signs of previous nailing on the canvases can also be observed on the rims of the canvas (Fig. 5, right). These paintings are apparently restored/repainted prior to their purchase by AQRM and there is no evidence to show these latter interventions have been performed by the restorers at AQRM. Tajan painting, however, has been resorted/relined at AQRM [26]. Although the stretchers of the paintings are the same size, the frames are with different size so that folded cards have been used to keep the stretchers tight in the frames. Also, small nails have been diagonally used to stich the frame to the stretcher (Fig. 5, right). The paintings have



**Fig. 5** (left) Sampling with a sharp scalpel from the rim of the canvas with no visible latter intervention and (right) the sign of previous nailing on the stretcher and nailing the stretcher to the frame

been varnished more than once and craquelures can be seen on the paintings. The varnishes can also be observed on the stretchers. The back side of the frames had been covered by kraft paper in order to avoid depositing dust behind the canvases. The traces of these papers are still on the frames.

The paintings are signed as “Mohammad-e naqqashbashi” and are among those works of Mohammad Ghaffari which are supposedly painted during his travels with Naser al-Din Shah over his camp in Mazandaran (the northern Iran) and prior to his move to Europe (see Table 1). All these works are oil paintings executed in 1292/1875 and are signed by a black ink with the same style of handwriting. Artistically speaking, the brushstrokes on the paintings are not entirely the same style in each painting and the composition of the painting is rather unusual with respect to the other works of Kamal al-Molk (see most of the works painted by Kamal al-Molk in Soheyli Khansari [20], pp. 218–367). The self-portrait of the painter is appeared on two paintings, i.e., Safiabad and Tajan (Figs. 3b, 4c). These two portraits show different style of painting with respect to the other parts of the paintings. Also, the facial appearance of the painter in these two paintings represent an elderly man. Over-paintings can be apparently seen by naked eyes across the paint layer.

### Kojur

This painting bears the following inscription on the front side:

*The picture of the Pul-e Mahal-e Kojur, the view is from the east on October 13th, 1875, in the voyage of the royal painter Mohammad-e naqqashbashi (Fig. 1b).*

The inscription on the rear side is:

*This painting is the work of deceased Kamal al-Molk and its authenticity is certified by experts including Mr Engineer Foroughi and in particular Mr Manuchehr Sane'i, the seller, whom this painting is purchased for AQRM and registered with the number 13376 in the registry booklet on March 9th, 1976.*

This latter inscription is signed by Manuchehr Sane'i, Aziz Parvahan, Darvish Kasraei, Asghar Khansari, Ali Najafi, Sadr al-Din Nobar, Mohammad-Taqi Javidi, Ali Ardalan and Ali-Akbar Taqavi (the expert from the Ministry of Culture and Art) (Fig. 1c). As the inscription on the retro side of the painting indicates, this painting has been purchased from the collector, Manuchehr Sane'i, by AQRM and the authenticity of the painting has been certified by Mohsen Foroughi (1907/8–1983/4), the son

of Mohammad-Ali Foroughi, Zoka al-Molk. Mohsen Foroughi was graduated from École Nationale Supérieure des Beaux-arts and was one of the founders of the Department of Architecture at the Tehran University. He was also senator and one of the antique dealers of Persian art [27]. According to Majd [28] and Muscarella [6], Mohsen Foroughi and his father were practicing as an art and antique dealer. Mohsen Foroughi had been even imprisoned for trading the art objects [29]. Manuschehr Sane'i (d. 1997) was the son of Ali-Mohammad Me'marbashi Sane'i, the well-known architect of the Qajar period. The uncle of Manuschehr Sane'i, Ismael Memarbashi, was one of the fondest friends of Kamal al-Molk in the Naser al-Din Shah's court. He was also a connoisseur of antiquaries and a collector.

### Farahabad

This painting also contains two inscriptions. The inscription on this painting is:

*The picture of royal excursion passing from the opening of the Shilat-e Farahabad River that is part of the Mazandaran Sea, 10 degrees towards north and on the left side it is spread to the east, on November 1st, 1875 (Fig. 2b).*

The inscription on the rear side is:

*This painting with its gilded frame (in a western-style frame) has the size of 124×94 cm, the work of Master Mohammad Ghaffari (Kamal al-Molk) that is painted on November 1st, 1875, and depicts the landscape of the passage of the Shah's army from the opening of the Shilat-e Farahabad River. The authenticity of this work is attested by Mr Senator Foroughi and Mr Ali-Akbar Taqavi the expert (connoisseurship) from the Ministry of Culture and Art. This is purchased from Mr Manuchehr Sane'i for AQRM and registered with the number 15076. The size of the painting itself is 100×70 cm and the above size is for the frame of the painting.*

This latter inscription is signed by Senator Engineer Foroughi, Ali-Akbar Taqavi, Mohammad Rahbar, Sohrab Riyahi, Mohammad-Taqi Javidi and Abbas Nethari (Fig. 2c).

### Safiabad

The inscription on this painting is as follows:

*The picture of Safiabad plain, Ashraf-e Mazandaran, on the heights of the Shah Abbas's mansion between south and east, November 1st, 1875, Mohammad-e naqqashbashi (Fig. 3b).*

(This inscription is obscured so that it is not clear if the data is November 1st or another day in November). On the retro side, the following inscription is written:

*This painting is the work of deceased Kamal al-Molk and its authenticity is certified by Mr Engineer Foroughi and in particular Mr Manuchehr Sane'i, the seller, whom this painting is purchased for AQRM and registered with the number 13377 in the registry booklet in March 9th, 1976.*

This inscription is signed by Manuchehr Sane'i, Aziz Parvahan, Darvish Kasraei, Asghar Khansari, Ali Najafi, Sadr al-Din Nobar, Mohammad-Taqi Javidi, Ali Ardalan and Ali-Akbar Taqavi (the expert from the Ministry of Culture and Art) (Fig. 3c).

### Tajan

This painting includes only an inscription on the front side (Fig. 4b) which is.

*The picture of the passage of the royal procession from the Tajan river in Sari, Mazandaran, the view from the west on November 12th, 1875, Mohammad-e naqqashbashi". On the left corner of this painting, the painter is portrayed while he is painting (Fig. 4c).*

This painting is relined and the inscription on the rear side is hidden under the relining fabric.

### Analytical setting

Since there were limitations in sampling the surface of the paintings, it was only performed on the edge of the paintings using a sharp scalpel from the areas with no clear evidence of latter interventions. Samples were in fact collected from the rims of the canvas near the stretcher and from the areas where the pigments were not exposed and no damages to the paintings would be visible (Fig. 5, left). Several colours including blue, white, green, red and yellow were collected from the paintings (Table 2).

The minute samples were placed on a motorised X-Y-Z stage and analysed by an XMF-104  $\mu$ -XRF from Unistans S.A. using a Jupiter 5000 X-ray tube from Oxford Instruments (50 W) equipped with a Mo target and an XR-100CR Si-PIN detector from Amptek at 35 kV and 500  $\mu$ A for 3 m in air while a Kumakhov polycapillary lens focused the X-ray beam on a spot smaller than 100  $\mu$ m in diameter. For SEM-EDS microanalysis, minute samples were coated with Au and observed/analysed under high vacuum by a Mira 3 field emission SEM from TESCAN at 20 kV. The  $\mu$ -Raman device used in this study was a Takram DL G-100 device from TEKSAN. The Raman measurements were performed by two 532 and 785 nm laser lines and four 600, 1200, 1800 and 2400

grooves/mm gratings which offered the spectral resolution between 2 and 10  $\text{cm}^{-1}$  depending on the grating and laser employed. Depending on the grating used in Raman measurements, specific spectral ranges which included most informative bands of the pigments under study were registered on a Peltier-cooled CCD.

## Results

### White pigments

The elemental analysis of the pigments performed by  $\mu$ -XRF and SEM-EDS showed that most of them include Mg, S, Ca, Zn, Pb, Ti and Ba (Table 2; Fig. 6; Additional file 1: Figs S1, S3, S4, S5, S6, S8 and S10). The most frequent white pigment, which was highly associated with Pb, showed a Raman band at 1050  $\text{cm}^{-1}$  attributed to the  $\nu_1$  symmetric vibration of carbonate group of lead white ( $2\text{PbCO}_3\cdot\text{Pb}(\text{OH})_2$ ) [30]. Lead white seems to be the main white pigment mixed with other pigments (in particular with blue to achieve different shades of blue). Lead white is one of the most common white pigments ever occurred in Iran. Lead white however is mainly reported to have occurred in the illuminated manuscripts [31] rather than wall paintings in Iran. The relatively easy process of making lead white using lead sheets and vinegar has made lead white a white pigment widely available in the Persian palette of painting. Niknejad and Karimy [32] provide an in-depth research and discussion in the manufacturing recipes of lead white in Iran.

Apart from lead white, three distinct white pigments occurred in the paintings under study which included Ca or Ca and Mg (evinced by SEM-EDS, see Additional file 1) as main elements (Table 2).  $\mu$ -Raman accordingly demonstrated that a sharp Raman band at 1123  $\text{cm}^{-1}$  which is assigned to the  $\nu_1$  vibrational mode of carbonate group in huntite ( $\text{Mg}_3\text{Ca}(\text{CO}_3)_4$ ) [33], a Raman band at 1009  $\text{cm}^{-1}$  which is ascribed to the  $\nu_1$  vibrational mode of sulphate ion in gypsum ( $\text{CaSO}_4\cdot 2\text{H}_2\text{O}$ ) [30] and at three bands at 714 and 1086  $\text{cm}^{-1}$  which are assigned to  $\nu_4$  and  $\nu_1$  symmetric vibrational modes of carbonate ion in calcite ( $\text{CaCO}_3$ ), respectively [30]. The fact is that these three white pigments, unlike lead white or rutile, show a relatively low hiding power (compare the refractive index of huntite, gypsum and calcite which are ca. 1.6, 1.5 and 1.4–1.6, respectively, to that of lead white and rutile which are ca. 2 and 2.7, respectively [34]) and are not therefore suitable to be used in oil paintings. Unfortunately, it was not possible to understand how these three latter white pigments were distributed in the paintings. However, it can be stated that they are used as the substrate of the paintings (preparatory layer). The fact nevertheless is that while the occurrence of  $\text{CaCO}_3$  and  $\text{CaSO}_4\cdot 2\text{H}_2\text{O}$  in the priming layer of easel paintings is fairly a usual

**Table 2** Summary of analytical data and results from the paintings under study

Painting	Colour	XRF		SEM-EDS		Raman		
		Elements	Figure	Elements <sup>2</sup>	Figure	Bands (cm <sup>-1</sup> )	Compound	Figure
Kojur	Blue	Pb, Fe, Ca, (Zn) <sup>1</sup>	6a	Pb Fe, (Al, Si, P, Mg, Ca)	S1 S2	1050 2154	Lead white Prussian blue	8a 8a
Farahabad	Blue	Pb, Fe, Ca, (Mn, Cu, Zn)	6b	Pb, (Ca)	S3	1050 2154	Lead white Prussian blue	8a
	White	Ca, Ti, (Zn, Fe)		Mg, Ca, Al, Si, Ti, (Ba)	S4	1123 450, 610 549	Huntite Rutile (Artificial ultramarine blue)	7d, 8c 7d, 8c 8c
Safiabad	Blue	Pb, Fe, Ca, (Mn, Zn)	6c	Pb, (Ca, Al)	S5	1050	Lead white	7a
				Ca	S6	268, 714, 1086 2154	Calcite Prussian blue	7b
	Dark blue	Pb, Ba, Fe, Cr, Ca, Zn	6c	Al, Si, Ca, Zn, Ba, Pb	S7	464, 631, 986 277, 711, 1087 1009 351, 838 434 252, 403	Baryte Calcite Gypsum Chrome yellow Zinc white (Azurite)	9a 9a 8b
	Pale blue	Pb, Ba, Fe, Ca, Cl, (Cu, Zn)		Pb S, Ca, Ba, (Na, Ti)	S8 S9	1050 986	Lead white Baryte	7e
	white	Ti, Ca, (Fe)	6d			447, 611 1086	Rutile Calcite	7c 7c
	Green	Cr, Ti, Fe, (Ca)	6e	Ti, (Mg, Al, Ca)	S10	551 451, 611 685, 745, 837, 1145, 1283, 1340, 1528	Chromium oxide Rutile Phthalocyanine blue PB:16	9b 9b 8d
	Red	Pb, Ca, Fe, Mn, (Cu, Zn)				1009 465, 631, 986	Gypsum Baryte	9c 9c
				Mg, Al, Si, K, Fe, (Pb, Ca, Ti, Cr)	S11	221, 290	Red ochre	9c

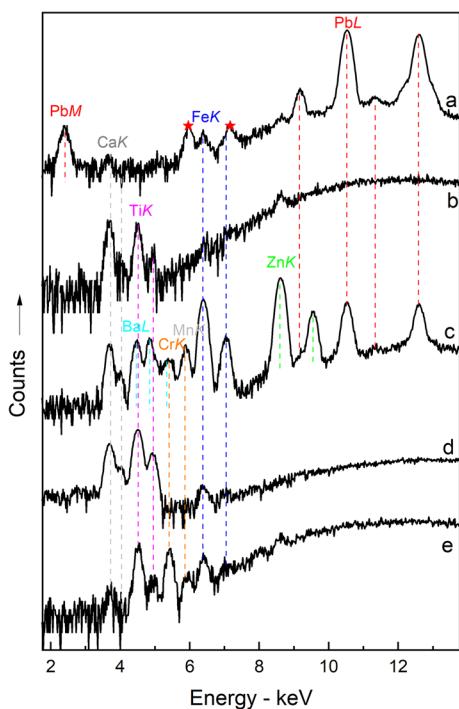
<sup>1</sup> The trace elements/compounds in parentheses<sup>2</sup> Carbon and oxygen are excluded from the list of elements (see Additional file 1)

observation, white huntite is highly unusual in this context. In addition, since Mg appeared in almost all samples (as SEM-EDS data demonstrated, Table 2) and the only Mg-bearing pigment detected by Raman was huntite, one may suppose that huntite is present in all paintings although Raman spectroscopy was only able to evince the occurrence of huntite in Farahabad.

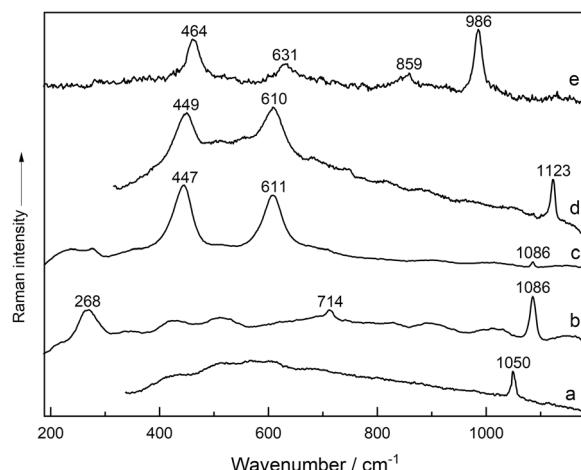
Huntite has been reported to occur in ancient Egyptian [35] and Roman painted materials [34]. Huntite, which is called *gel-e sefid* or *gel-e giveh*, has been also widely used in Iran as painting material [36, 37]. The widely accessible huntite deposits in central Iranian plateau [38] has made Persian painters able to use huntite as white pigment since the twelfth century [39]. However, there is no report which supports the

occurrence of huntite as white pigment in Persian illuminated manuscripts or easel paintings.

Apart from these four white pigments, three other white pigments were diagnosed in the paintings which are considered modern pigments. The first one, which was highly associated with Ba (Fig. 6c), demonstrated several Raman bands at 464, 631 and 986 cm<sup>-1</sup> that are driven from the  $\nu_2$ ,  $\nu_4$  and  $\nu_2$  vibrational modes of sulphate group in baryte ( $\text{BaSO}_4$ ), respectively [30]. Baryte was mainly found in chrome yellow (see the section *Pigments other than white and blue colourants*) and, therefore, is used as extender in this yellow pigment. Although the natural baryte deposits are available, it never became in common use as white pigment before 1782 [40]. Baryte has also been reported as a white extender mixed



**Fig. 6**  $\mu$ -XRF spectra of **a** from the blue colour in Kojur, **b** white colour in Farahabad, **c** dark blue colour in Safiabad, **d** white and **e** green colours in Tajan



**Fig. 7** Raman spectra of **a** lead white in the blue colour of Safiabad, **b** calcite in blue colour of Safiabad, **c** rutile and calcite in the white colour of Tajan, **d** huntite and rutile in the white colour of Farahabad and **e** baryte in the pale blue colour of Safiabad

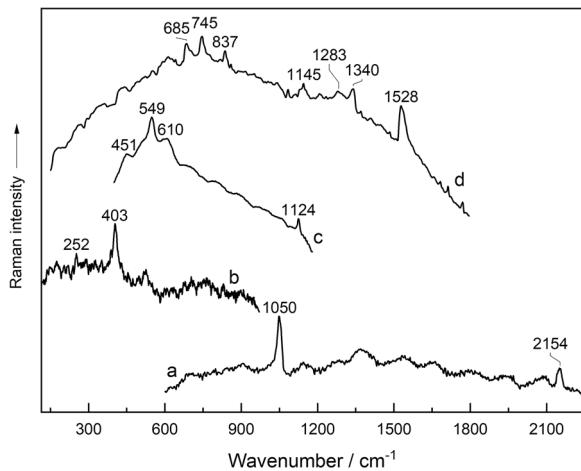
with chrome yellow [41], which is consistent with our observation.

In addition to baryte, a white pigment highly enriched with Zn (Fig. 6c), showed a Raman band at ca.  $435\text{ cm}^{-1}$  which is linked with  $E_2^{\text{high}}$  vibrational mode of zinc white ( $\text{ZnO}$ ) [30]. The fact is that the detection of zinc white by  $\mu$ -Raman was fairly difficult and it was diagnosed after multiple attempts performed to identify the Zn-bearing pigment. This may be related to the fact that zinc white prompts the degradation of paintings by forming Zn soaps when mixed with an oil binding medium [42]. Be degraded or not, zinc white was first produced in 1780 and was popular in the mid-nineteenth century [43]. The most controversial white pigment, which was highly associated with Ti, showed two broad Raman bands at  $448$  and  $610\text{ cm}^{-1}$  which are to be from the  $E_g$  and  $A_{1g}$  vibrational modes of rutile ( $\text{TiO}_2$ ) [44], was identified in Farahabad and Tajan paintings (Fig. 7; Table 2). It must be emphasised that the occurrence of rutile in works of art may not be considered as evidence of industrial manufacture since mineral rutile was in use as artists' pigment prior to the introduction of the synthetic product. However, it should be noted that the natural mineral rutile is never the brilliant as the synthetic rutile because the natural mineral contains elements such as Fe. Since the rutile occurred in the paintings contained no considerable

amount of Fe in the composition (Additional file 1: Fig S10), it is suggested that the rutile occurred in the paintings is most certainly a synthetic product. Synthetic rutile was first manufactured and used as artists' pigment in the 1940s [45].

#### Blue colourants

As for the white pigments,  $\mu$ -Raman revealed various blue pigments in the paintings. First, a spare use of azurite ( $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$ ) was evinced by Raman bands at  $86$ ,  $253$  and  $403\text{ cm}^{-1}$  related to the lattice modes of this pigment [30] (Fig. 8b). Azurite is a blue pigment which appeared first in Iran from the fourteenth century and used widely in the Persian palette of painting since then [46]. Apart from azurite, synthetic ultramarine blue ( $\text{Na}_{8-10}\text{Al}_6\text{Si}_6\text{O}_{24}\text{S}_{2-4}$ ) was only observed as a very rare blue pigment in Farahabad with a Raman band at  $549\text{ cm}^{-1}$  attributed to  $\nu_1$  mode of  $\text{S}_3^-$  in ultramarine blue (the occurrence of artificial ultramarine blue was confirmed by its small and uniform particle size under microscope) [34]. Artificial ultramarine blue was first manufactured in the 1820s and became a common and cheap blue artists' pigment ever since [47]. Artificial ultramarine blue has also been reported to occur in Persian wall paintings from the twentieth century [48]. Another blue pigment whose scarce occurrence was evinced only in Tajan was blue phthalocyanine PB:16 ( $\text{C}_{32}\text{H}_{18}\text{N}_8$ ) which demonstrated the most important Raman bands at  $685$  (related to the macrocyclic ring breathing),  $1340$  (assigned to pyrrole C-C stretching mode) and  $1528\text{ cm}^{-1}$  (attributed to pyrrole C=C vibrational mode) [49] (Fig. 8d). Blue phthalocyanine PB:16 is



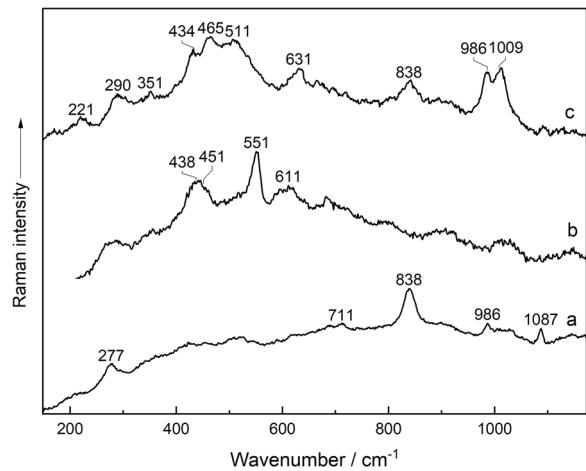
**Fig. 8** Raman spectra of **a** Prussian blue mixed with lead white in the blue colour of Kojur, **b** azurite in the dark blue colour of Safiabad, **c** ultramarine blue, rutile and huntite in the white colour of Farahabad and **d** blue phthalocyanine PB:16 in green colour of Tajan

a modern pigment which was first produced and used as blue pigment in 1935 [50]. Since Tajan is recently relined and restored at AQRM, it is not surprising to observe this pigment in the restored painting although there is no record which painting materials have been used by the restorer. This should be emphasised that these three modern pigments are only sparingly observed in the samples under study and any solid conclusion based on the occurrence of these pigments may not be decisive.

Apart from these three blues, the main blue pigment in all painting was Prussian blue ( $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$ ), which showed the Raman band at  $2154 \text{ cm}^{-1}$  (assigned to the CN stretching mode) (Fig. 8a) [30]. It should be mentioned that Prussian blue was always mixed with variable amounts of lead white based on the desired shade of blue. Since Prussian blue is very dark in colour, it is not surprising to see it mixed with white pigment. Prussian blue is one of the first synthetic pigments which was first manufactured in 1704 [51]. It has also been reported as blue pigment in the works of art appeared in Iran [8, 10]. The discolouration of Prussian blue is a well-known phenomenon which is considered as result of reacting with oil medium [52, 53]. Therefore, one may expect a major change of colour in the Prussian-blue-painted areas with respect to the original blue adopted by the painter of the works under study.

#### Pigments other than whites and blue colourants

Three other pigments were also identified within the paintings. Chrome yellow ( $\text{PbCrO}_4$ ) with a Raman band at  $838 \text{ cm}^{-1}$  (assigned to  $\nu_1$  symmetric stretching of the chromate ion) was diagnosed to be mixed with baryte in



**Fig. 9** Raman spectra of **a** chrome yellow, calcite and baryte in the dark blue colour of Safiabad, **b** chromium oxide green and rutile in the green colour of Tajan and **c** chrome yellow, gypsum, zinc white, barite and hematite in the red colour of Tajan

Safiabad. Chrome yellow was first manufactured in the 1810s [54]. It has also been reported as yellow pigment in wallpapers used in Iran [41]. Similar to Prussian blue, chrome yellow is also prone to discolouration. Monico et al. [55] have shown that chrome yellow in presence of sulphate ions and light is darkened due to the converting  $\text{Cr}^{VI}$  to  $\text{Cr}^{III}$ . Thus, the original appearance of the yellow painted areas may be different from what the painter of the works of under study desired.

Another Cr-bearing pigment, which showed no appreciable amount of Pb (Fig. 6), was green chromium oxide ( $\text{Cr}_2\text{O}_3$ ) as a Raman band at  $551 \text{ cm}^{-1}$  related to symmetric Cr-O-Cr vibrational mode demonstrated (Fig. 9) [30]. Green chromium oxide was first produced in 1812 (popular in the mid-nineteenth century) [55] and has never been reported to occur in any Persian painting. This finding is interesting as green colour in Persian painted arts has always been linked with Cu. Several scientific studies show that atacamite ( $\text{CuCl}_2 \cdot 3\text{Cu}(\text{OH})_2$ ) [36, 37, 39, 57, 58], verdigris (hydrated copper acetate) and malachite ( $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ ) have been reported to occur in Persian pictorial arts [31, 59].

Apart from these pigments, red ochre ( $\text{Fe}_2\text{O}_3$ ) was identified as the only red pigment identified in Safiabad (Fig. 9c). The occurrence of red ochre was in fact evinced by the Raman bands at 221 (due to  $\text{A}_{1g}$  mode) and  $289 \text{ cm}^{-1}$  (due to  $\text{E}_g$  mode) [30]. Fe-based reds are among the earth pigments which have been used since earliest times in painted works. The sources of red ochre are available worldwide and, therefore, there is no wonder if one identifies this pigment in an artwork from the late nineteenth century.

## Discussion

### Pigments as evidence

The occurrence of four blue and seven white pigments in the paintings might indicate different phases of intervention or retouching on the painting. Apart from azurite, white huntite, gypsum, calcite, red ochre and lead white, all the pigments identified in these four paintings are first appeared in the painters' palette from the eighteenth century onwards as discussed earlier. Since Prussian blue, baryte, artificial ultramarine blue, zinc white, green chromium oxide and chrome yellow are reported to have been manufactured in 1704, 1782, the 1820s, 1780, 1812 and the 1810s, the occurrence of these pigments in the works under study may not be surprising as they are supposedly painted in 1292/1875. Nonetheless, the occurrence of rutile, as the white pigment, and phthalocyanine blue PB:16 is a matter of controversy. Since rutile was first appeared as artists' pigment in the 1940s and phthalocyanine blue PB:16 was first manufactured in 1935, the appearance of these two pigments on Tajan and Safiabad must be justified as these paintings are supposed to be executed in 1292/1875. As mentioned before, the paintings have undergone previous restorations and the white rutile and phthalocyanine blue PB:16 may have been introduced to the paintings as latter interventions. One should nevertheless note that since the sampling was only performed from the edge of the paintings with no clear evidence of latter interventions from one hand and rutile was identified under varnish layer employed in restorations, on the other hand, it is less likely to believe that rutile was introduced as a restoration material (it should be mentioned that since the paintings are not likely to be re-varnished on the rims, where the samples were collected from, the varnish on rutile is most probably the original varnish and, consequently, rutile is an original pigments used on the paintings.) The variety of the pigments (and in particular white pigments) identified in four paintings supposedly executed in a short time interval (less than 1 month in 1292/1875) may also pose a serious question about the originality of the paintings.

As mentioned earlier, white huntite occurred in Farahabad painting. Despite several Raman measurements performed on the areas with the occurrence of huntite, no signals from Mg or Ca oxalates were detected in the Raman spectra. It is an interesting observation because white huntite occurred in any painted Persian painting has contained glushinskite ( $MgC_2O_4$ ), weddellite or whewellite [36, 37, 39] even in the paintings executed within the time span that the works under study have been painted [48]. The occurrence of oxalates is believed to be triggered from the degradation of organic binders of the paintings and the formation of oxalic acid and its reaction with pigments [60]. This is a process that cannot

occur in a short period of time. Therefore, the absence of Mg or Ca oxalates in the painting under study may be indicating that the paint layer has not been aged.

Concerning the use of modern imported pigments in the works of Kamal al-Molk, it should be mentioned that Kamal al-Molk has imported some of the paintings he executed in Europe to Iran [61] and, therefore, the occurrence of the modern pigments on the paintings must not be surprising. In addition, Dehbashi [62] mentions that Kamal al-Molk used to employ painting materials imported to Iran as well as the local Iranian colourants and even encouraged his students to use these pigments. However, it must be emphasised that the four paintings under study have been supposedly painted prior to his visit from Europe and, therefore, the pigments occurred in the paintings must not have been imported by Kamal al-Molk himself from Europe to Iran and, moreover, these paintings are not executed in Europe.

### Art historical controversies

Museums are often reluctant in concluding to fake origin of artworks in their collections based only on the pigments found on them. Works of art may be executed in a certain period and repainted/restored in a distinct time. The unknown distribution and abundance of the modern pigments identified on the paintings also prevents one to conclude about the authenticity of the whole painting. These pigments may be limited to in-paintings that have occurred in an unknown period of time. Therefore, art historical discussions may help to strengthen or to reconsider the assumptions that scientific observations arose. There are several historic evidences that comply with the controversy that the scientific study of the paintings raised. Some of these controversies are argued below.

- The date appeared on the painting (i.e., 1292/1875) signed under the title 'naqqashbashi' does not fit with the date that Mohammad Ghaffari became the naqqashbashi of the court (i.e., ca. 1300/1883). In fact, the date appeared on the paintings is about 8 years after Mohammad Ghaffari was entitled as 'naqqashbashi' of the court (see *Introduction*).
- Considering the more acceptable date of birth for Mohammad Ghaffari (i.e., 1275/1859) (see *Introduction*), he must have been ca. 17 years old when the paintings under question were executed. It is highly unlikely that these paintings to be the works of a young 17-year-old painter.
- The portraits of the painter in the paintings Safiabad and Tajan is depicted as an elderly man while Kamal al-Molk should have been ca. 17 years old at the time of executing the paintings.

d) Apart from the paintings under study, the earliest painting which can be attributed to Kamal al-Molk, based on his own statements, is the portrait of E'tezad al-Saltaneh, which could not have been painted prior to 1298/1880 (see *Introduction*). The other oldest known work of Kamal al-Molk is 'the royal excursion' painted in 1299/1881 [62], painted well after the execution date of the paintings under study. It is peculiar that no other paintings have been reported from Kamal al-Molk painted from 1292/1875 to 1298/1880.

e) After founding the Academy of Fine Arts, Kamal al-Molk collected and restored his paintings, the act that he was performing up to his final years of life [62]. Therefore, one can attribute the works under study to the paintings restored by Kamal al-Molk himself. However, it is unlikely that these paintings are among this type of works because at the period when he was at the Academy of Fine Arts, he no longer had the 'naqqashbashi' title but he had owned the Kamal al-Molk title (he became Kamal al-Molk in ca. 1311/1894, see *Introduction* and Table 1).

f) It was often common that the respected pupils sign on behalf of the masters upon the permission that was granted by the masters. Pupils could also copy the masters' works. For example, Kamal al-Molk signed one of the self-portraits painted by his apprentice, Ne'mat-allah Khan, after he added some final retouching [20]. Therefore, the paintings under study may be considered from this sort of Kamal al-Molk's paintings. However, Kamal al-Molk was strict in differentiating between forgery and copy and emphasised that the copied works must be stated that are copied otherwise they are forgeries [20].

g) The works under study are not listed among the 73 works listed by himself in his interview with Ghani [23] and those collected by Karimzadeh Tabrizi [25].

h) The locations mentioned in the front inscriptions of the paintings have been registered in the memoirs of E'temad al-Saltaneh from the Naser al-Din Shah voyage to Mazandaran in 1292/1875 (Naser al-Din Shah had several travels to Mazandaran including in 1281/1864, 1282-3/1866, 1292/1875 and 1299/1882). However, there is no record in the memoirs of these voyages occurred from 1292/1875 to 1313/1895 that shows Mohammad Ghaffari accompanied the Shah to Mazandaran in his voyage [63, 64].

i) Kamal al-Molk mentions that he travelled with the Shah to Mazandaran and have executed paintings from landscapes over these travels (he however does not mention when exactly he travelled with the Shah). However, he mentions that these paintings are all torn out by Movathaq al-Doleh, the vizir of the court [23]. Therefore, if they have survived, the traces of repairs and latter restorations should be clear on the canvas. However, there is no signs of damage on the canvases under study.

j) The size of the canvas and stretchers in all these painting is also questionable. No other works of Kamal al-Molk survived and catalogued has the same size of these four paintings (i.e., 100×70 cm) (see the size and list of the paintings collected by Ashraf and Diba [17]). The canvas size of the paintings is also unusual in the larger context of the easel paintings. Paintings with the same size, if they are not totally non-existent, are very rare [65]. This size is mostly associated with the metric system of ISO 216, which is used for describing paper and card size, introduced in the 1920s.

## Conclusions

Questions about the authenticity of the works of art cannot solely be addressed based on art historical or scientific studies. Multi-disciplinary researches often cope better with the questions of this kind. The current article represents one of the cases which demanded both scientific and art historical evidences for a better understanding of the works of art. In this study, a question, which was raised by scientific research, was expanded and elaborated with an in-depth study on the history of four painting allegedly attributed to Kamal al-Molk. The identification of modern pigments including Prussian blue, artificial ultramarine blue, zinc white, blue phthalocyanine PB:16 and rutile identified on four easel paintings of Kamal al-Molk created a clearer picture of the history of the paintings and posed serious question about their authenticity. We showed that when scientific and art historical research meet, a more robust decision may be acquired. For future research, it is suggested that authentic works of Kamal al-Molk which are gifted by himself to the Parliament Museum of Iran are scientifically investigated and the collected data are compared with those presented in this study in order to come up with a more robust conclusion about the authenticity of the paintings.

## Supplementary Information

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**Additional file 1.** EDS spectra and semi-quantitative data from the samples under study.

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#### Author contributions

S.R. developed the idea, performed sampling, contributed in the art historical discussion and helped in developing the first draft; P.H. performed  $\mu$ -XRF,  $\mu$ -Raman, SEM-EDS, wrote the first draft of the manuscript and developed scientific analysis and discussion.

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#### Declarations

##### Ethics approval and consent to participate

Not applicable.

##### Consent for publication

Not applicable.

##### Competing interests

The authors declare that they have no competing interests.

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