

# Characterization and Degradation Analysis of Pigments in Paintings by Martiros Sarian: Attenuated Total Reflection Fourier Transform Infrared Spectroscopic Imaging and X-ray Fluorescence Approach

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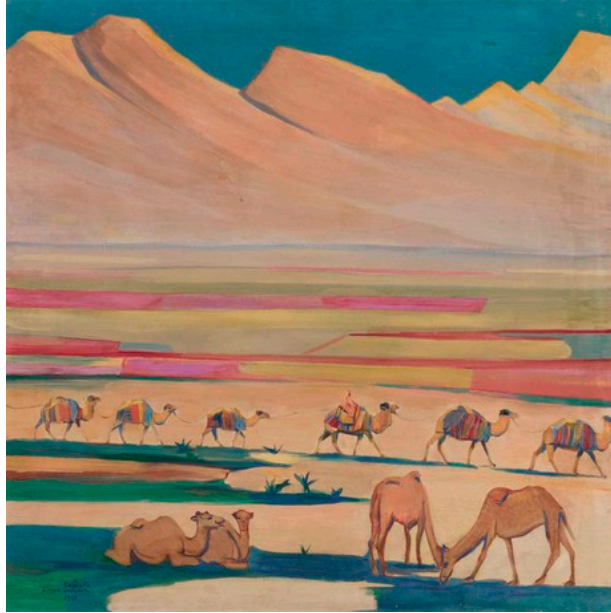
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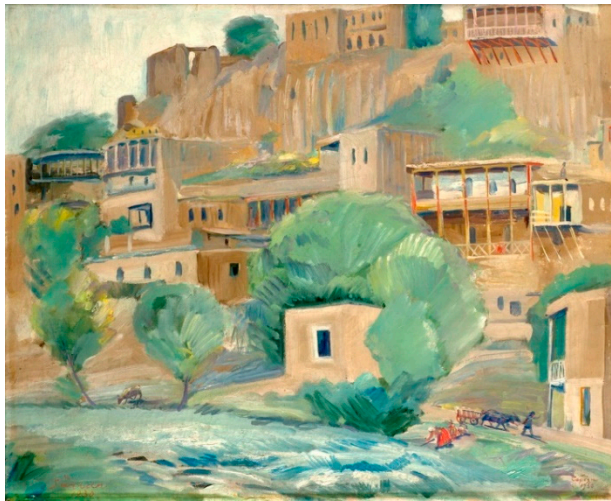
(a)



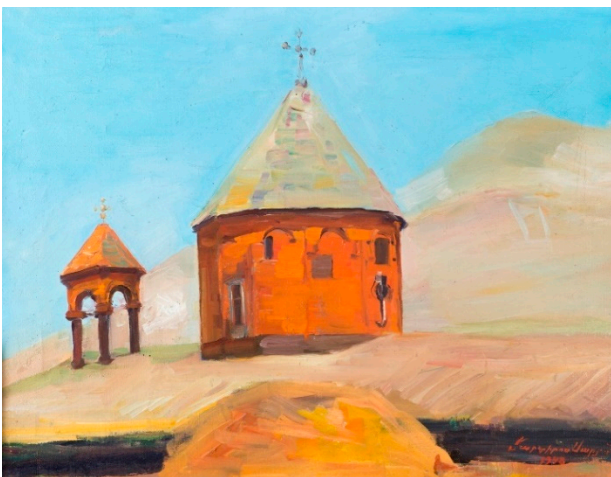
(b)



(c)



(d)



(e)

**Figure S1.** Five paintings housed at the Martiros Sarian House-Museum in Armenia: (a) *Morning in Stavrino* (1909), (b) *Arabian Dancer* (1913), (c) *Caravan* (1926), (d) *Yerevan Zangu River* (1931), and (e) *Kirovakan* (1948). Those pictures of the paintings are provided by Sophie Sarian, the Chief Curator at Martiros Sarian House-Museum.



**Figure S2** Pigment powder samples on the CaF<sub>2</sub> plate

**Table S1** XRF data of the blue and the light blue pigments

Color	Blue								Light blue	
Painting	<i>Morning in Stavrino (1909)</i>		<i>Arabian Dancer (1913)</i>		<i>Caravan (1926)</i>		<i>Yerevan Zangu River (1931)</i>		<i>Kirovakan (1948)</i>	
Quality/ Quantity	Zn	41.475 %	Zn	70.761 %	Pb	62.298 %	Zn	45.931 %	Zn	90.243 %
	Ca	18.057 %	Si	6.478 %	Ca	13.065 %	Sn	27.969 %	Ca	3.597 %
	S	9.69 %	S	5.27 %	Co	5.647 %	Co	13.582 %	Sn	1.911 %
	Si	7.504 %	Al	4.711 %	Al	4.862 %	Si	3.953 %	Co	1.658 %
	Cr	6.499 %	Ca	3.769 %	Fe	3.895 %	Ca	3.805 %	Si	0.993 %
	Al	5.213 %	Pb	2.574 %	Zn	3.839 %	Fe	1.873 %	S	0.706 %
	Pb	3.69 %	Fe	2.534 %	S	3.606 %	Cl	1.694 %	Cl	0.402 %
	Cl	2.715 %	K	0.951 %	Cd	1.42 %	Cr	1.027 %	Fe	0.209 %
	Fe	2.268 %	Cl	0.761 %	Cl	0.869 %	As	0.167 %	Cu	965.8 ppm
	Ti	0.763 %	P	0.575 %	Cr	0.209 %			As	914.8 ppm
	Cu	0.538 %	Cd	0.467 %	V	0.121 %			Cr	460.7 ppm
	As	0.484 %	Cr	0.381 %	Sr	859.5 ppm			P	456.7 ppm
	P	0.364 %	As	0.211 %	Ga	828.1 ppm				
	Cd	0.227 %	Ga	0.147 %						
	Co	0.22 %	Co	0.131 %						
	Mn	917.6 ppm	Cu	0.107 %						
	Ga	789.1 ppm	Ti	988.7 ppm						
	Ni	674.9 ppm	Mn	527.8 ppm						
	Sr	544.2 ppm	V	199.7 ppm						

\* In the obtained XRF results, specific elements are observed to exhibit a concentration of 0 ppm. This occurrence stems from the fact that while these elements were detected during the qualitative analysis phase, their corresponding signals were of insufficient strength to facilitate accurate quantification in the subsequent quantitative analysis.

**Table S2** XRF data of the green and the blue-green pigments

Color	Green								Blue-green	
Painting	<i>Morning in Stavrinio (1909)</i>		<i>Arabian Dancer (1913)</i>		<i>Yerevan Zangu River (1931)</i>		<i>Caravan (1926)</i>		<i>Caravan (1926)</i>	
Quality/ Quantity	Ca	72.222 %	Zn	64.572 %	Zn	54.605 %	Pb	75.037 %	Pb	73.932 %
	Cr	7.424 %	Na	8.699 %	Pb	14.551 %	Ca	9.221 %	As	9.722 %
	Si	3.865 %	S	6.005 %	Si	9.074 %	Cr	7.785 %	Cu	7.015 %
	S	3.552 %	Si	4.28 %	Ca	6.237 %	Mg	3.855 %	Ca	5.173 %
	Al	3.359 %	Ca	4.131 %	Al	4.801 %	Fe	1.284 %	Co	2.143 %
	Fe	3.228 %	Al	2.94 %	Fe	2.801 %	Zn	1.086 %	Zn	0.841 %
	Zn	2.794 %	Cr	2.331 %	S	1.84 %	Cd	0.764 %	Fe	0.451 %
	Cl	1.217 %	Fe	2.106 %	Cl	1.816 %	Cl	0.714 %	Cl	0.311 %
	P	1.08 %	Pb	1.578 %	Cr	1.369 %	Ti	0.116 %	Sn	0.174 %
	Pb	0.418 %	Ti	1.505 %	Co	1.246 %	Sr	690.2 ppm	Sr	863.2 ppm
	Co	0.399 %	P	0.683 %	As	0.756 %	Mn	502.5 ppm	Cr	757.2 ppm
	Ti	0.2 %	Cl	0.418 %	Er	0.598 %	Zr	195.8 ppm	Ti	655 ppm
	Cu	0.127 %	Co	0.296 %	V	0.124 %			Zr	105.3 ppm
	As	649.7 ppm	Cd	0.2 %	Ga	0.107 %				
	Mn	505.8 ppm	Sn	913 ppm	Mn	747.8 ppm				
			As	868.2 ppm						
			Sr	790.6 ppm						

**Table S3** XRF data of the yellow and the brown pigments

Color	Yellow				Brown	
Painting	<i>Morning in Stavrinio (1909)</i>		<i>Caravan (1926)</i>		<i>Caravan (1926)</i>	
Quality/ Quantity	Si	24.419 %	Pb	87.827 %	Pb	92.339 %
	Ca	21.482 %	Ca	4.994 %	Ca	3.044 %
	Zn	14.826 %	Cd	2.742 %	Cd	2.339 %
	Cl	8.94 %	Ti	1.219 %	Zn	1.055 %
	Pb	7.658 %	Cl	1.063 %	Al	0.346 %
	S	7.583 %	Fe	0.851 %	Fe	0.305 %
	Fe	7.213 %	Zn	0.737 %	Cr	0.193 %
	Cr	2.975 %	V	0.253 %	Co	0.16 %
	Sn	2.479 %	Cr	0.211 %	Sr	777.8 ppm
	Ti	2.041 %	Sr	828.5 %	Ti	632.3 ppm
	As	0.383 %	Zr	208.9 %	Cu	446 ppm
					Zr	320.7 ppm
					Rb	20.5 ppm

**Table S4** XRF data of the red and the orange pigments

Color	Red				Orange	
Painting	<i>Arabian Dancer</i> (1913)		<i>Caravan</i> (1926)		<i>Kirovakan</i> (1948)	
Quality/ Quantity	Zn	63.831 %	Pb	45.645 %	Zn	67.757 %
	Na	12.947 %	Cl	19.636 %	Si	12.517 %
	S	9.227 %	Co	10 %	Ca	10.242 %
	Ca	3.384 %	Ca	9.61 %	Fe	3.999 %
	Al	2.512 %	P	6.532 %	Cl	2.117 %
	Si	2.181 %	Fe	3.648 %	S	2.085 %
	Cd	1.433 %	Zn	2.52 %	Ti	0.389 %
	Fe	1.242 %	Er	1.841 %	Cr	0.341 %
	P	1.187 %	Cr	0.56 %	V	0.207 %
	Cl	0.612 %	Ga	87.5 ppm	As	0.128 %
	K	0.427 %			Co	0.119 %
	As	0.399 %				
	Cr	0.372 %				
	Ti	0.106 %				
	Co	920.1 ppm				
	Mn	474.2 ppm				