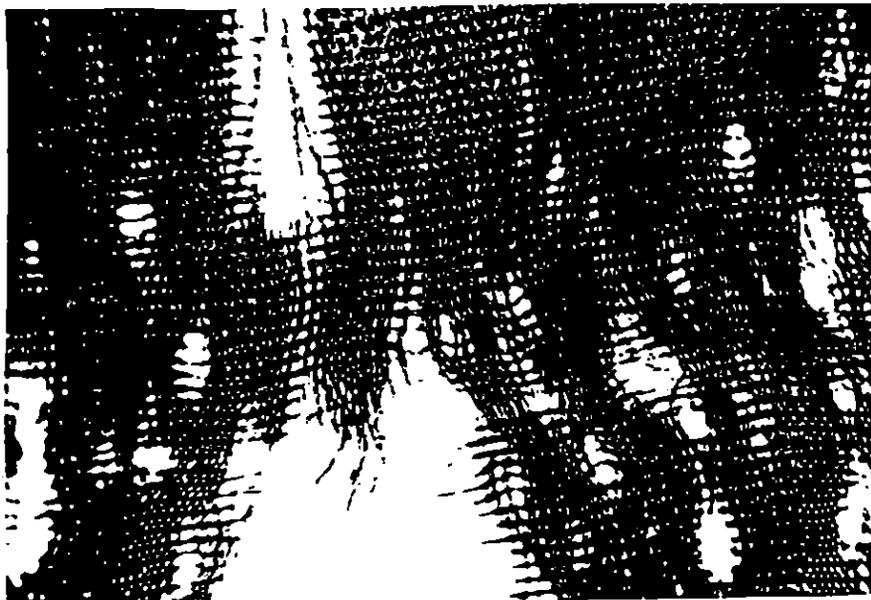

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CHARACTERIZATION AND PRESERVATION OF WEIGHTED SILK



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CHARACTERIZATION OF HISTORIC WEIGHTED SILK

The information presented here is the first phase of a two part study entitled Characterization and Preservation of Weighted Silk. In this first phase, historic silk textiles were examined for deterioration and analyzed for the presence of weighting agents. In the second phase, currently in progress, several preservation treatments are being tested on historic and newly weighted silks. The results of the second phase of the study will be forthcoming.

INTRODUCTION

Textiles, probably more than any other medium are subject to deterioration. ¹ In the past, the care of these fragile and important artifacts has been given a low priority and due to this lack of attention and information regarding their care, many textiles are in a state of "severe and irreversible damage". ² However, one category of textiles is almost always singled out as the most deteriorated and difficult to conserve: silk textiles from the late nineteenth and early twentieth centuries.

One reason why these silks from the late nineteenth and early twentieth centuries are deteriorating, while silk artifacts from the eighteenth century still survive in good condition ³, may be traced to the industrial practice of silk weighting. Silk weighting is defined as the addition of various substances onto the silk fiber to increase its weight. During the late nineteenth and early twentieth centuries, silk fabric and yarn was weighted or "loaded" with agents to the point that adulteration of the product became excessive.⁴ In discussing the silk industry, one critic noted that the damask curtains at Hampton Court Palace, which were woven in the seventeenth century, were changed in color but still

strong: "If they had been made of loaded silk they would have powdered to dust long before the battle of Waterloo." ⁵

Silk weighting is now internationally recognized by curators and conservators of textiles and costumes as a probable cause of the rapid deterioration of silk artifacts from this period. Although a connection has been made between severe cracking and tearing and silk weighting⁶, the phenomenon is not well understood.

Physical and Chemical Nature of Silk

Silk is a polypeptide made up of only four amino acids: glycine, alanine, serine and tyrosine in varying amounts and locations in the peptide chain.⁷ Silk contains carboxyl (COOH) and amino (NH₂) groups, such that it is both acid and basic in nature. This amphoteric quality accounts for the ease of direct dyeing in both acid and basic dyestuffs. Silk also has a moisture regain of 11%. ⁸ The fiber has been noted for thousands of years for its strength, toughness and smooth, soft feel. Each fibroin fiber is believed to consist of 20-30 bundles of highly oriented fibrils held together through interfibrillar tie molecules, contributing to the mechanical property of silk. The high degree of crystallinity responsible for its strength also makes it resilient, well shaped, and a poor conductor of heat and electricity. ⁹

Silk Manufacturing Practices

Silk is a continuous protein filament composed of a fibrous or crystalline bipolymer called fibroin which is surrounded by a non-fibrous amorphous bipolymer called sericin. Fibroin accounts for 75-90% of the fiber and sericin 10-25%. In silk manufacture, the sericin is removed to expose the soft and glossy fibroin, which is more receptive to dyes. The removal of sericin is known as degumming, scouring or boiling off.

Removal can be accomplished in a mild alkaline solution because of the difference in solubility between fibroin and sericin.

The removal of the gum can amount to 25% of the original silk weight, and since silk yarn has been generally sold by weight, this resulted in a loss of profit for the manufacturer. To compensate for the weight lost in degumming, silk was weighted with various substances (metal oxides were the most common). The weight gain has been attributed to the attachment of metal oxide to the amino acid glycine.¹⁰ Replacing the same amount of sericin lost with a weighting agent was called "weighting to par" or 100% weighting.¹¹ When it was discovered that silk could absorb a greater amount of weighting agent than sericin lost in degumming, the practice was ripe for abuse.¹² The overweighting of silk was rampant in the late nineteenth and early twentieth century in order to make silk more competitive and available to a wider market. The issue of excessive silk weighting was raised by consumers and was finally resolved by regulations and labeling standards imposed by the Federal Trade Commission in 1932 and updated in 1938. The industry could not use the terms: "pure dye silk", "all silk", or "100% silk" if there were any weighting agents whatsoever. After that time, any silk which did contain weighting agents had to be disclosed.¹³

Silk Weighting Agents

Investigation of silk weighting patents reveals an astonishing variety of patent ingredients and practices. Silk weighting agents, as indicated by the patents, ran the gamut of both organic and metallic material. Organic weighting agents included sugar, casein, logwood and tannin. However, metallic salts, and especially tin salts were the most common weighting agents, as well as the most damaging. Tin chloride was

the weighting agent of choice for light colored fabrics, while iron oxides were used for dark colored fabrics.¹⁴

The patents document a great deal of concern about the damaging effect of weighting agents on silk, and damage from tin weighting, in particular. Judging from the description of the ingredients in the tin-weighting process, the acidic nature of the formulation probably predisposed the fiber to later deterioration by acid hydrolysis. Even as a dye agent, the injurious effect of stannic acid used in the weighting of silk was known and documented in an 1894 patent:

The stannic acid thus retained by the fiber in time renders fiber brittle and rotten; and it becomes to a greater or less extent destroyed and unfit for use. (US 532,660).

Upon introduction of a new process, tin-phosphate-silicate weighting (US 583,725 patented in 1897), an even worse problem was encountered. Spontaneous deterioration, occurring within even a few months was reported.¹⁵ In this process, the silk was first placed into a solution of stannic chloride, called pinking. The silk was then placed in a bath of sodium phosphate forming a basic tin phosphate. The next treatment with sodium silicate converted the basic tin phosphate into tri-silicate of tin. This reaction produced a highly acidic bath which could be detrimental to the fiber. In 1897 a German patent described a method of steeping in successive baths of stannic chloride, soluble phosphate and sodium silicate. This was the process adopted for most of silk industry from 1900-1920. Later patents suggested the use of chromium, aluminium or iron salts either before or after the tin weighting. The use of phosphoric or formic acid was also patented as a swelling agent. Other weighting

agents have included metal oxides of zinc, lead, iron, zirconium, and antimony to name a few.¹⁶

The first United States patent for a weighting agent was obtained in 1883 and by 1906 a subcategory of patents was developed specifically for the purpose of protecting tin-weighted silk with the use of antioxidants. These so-called protective patents form the basis of research for preservation treatments undertaken in the second phase of this study.

DESCRIPTION OF THE STUDY

Statement of Purpose

The purpose of this study was to provide a systematic investigation of the deterioration of weighted silk textiles. The characterization phase documented, both visually and instrumentally, deterioration found on a sample group of historic textiles. In addition, the historic silk textiles were analyzed in order to determine the presence of weighting agents. An underlying purpose in using a variety of procedures was to document which treatments and types of examination might be most useful for the museum profession.¹⁷

Samples

The majority of the samples used for this study were taken from dated silk garments. These silk garments were deaccessioned from the Neville Public Museum in Green Bay, Wisconsin and donated to the University of Wisconsin for this research project. In total, 34 historic garments, dating from 1850-1930 were used for the study (Table 1). New silk fabric selected for comparison is unweighted plain woven Chinese silk habutae (Test Fabric, Style 604).

Method of Study

Descriptive visual examination and instrumental analysis was used to present a picture of the deterioration found on historic silks. The visual examination of the textile condition is accomplished by photographing the fabric surface at close range to document condition using a Canon EOS camera mounted on a Olympus SZ microscope with 2.5x magnification lense. An examination of fiber deterioration is accomplished using the photomicrograph component of the Scanning Electron Microscope with magnification up to 2000.

The question of what weighting agents are found on historic textiles is explored using several analytical tools. Two analytical techniques, the Scanning Electron Microscope with Energy Dispersive X-Ray Spectrophotometer (SEM/EDS) and Neutron Activation Analysis (NAA) were initially chosen because small size samples could be utilized and the instruments were available at the University of Wisconsin Engineering Department. Scanning electron microscope analysis has recently been used on weighted silk at the Smithsonian Analytical Laboratory¹⁸ and Neutron Activation Analysis was reported in a study undertaken at Kansas State University.¹⁹ However, both tests are expensive and require the use of very sophisticated equipment. Therefore, another test, Inductively Coupled Plasma (ICP), was added because it is readily available at any Soil and Plant Analysis laboratory and is inexpensive. In addition, this test, unlike the others, could be used for analysis of lead in the historic samples. However, ICP has not been described in the literature as a method for analyzing textiles and requires a larger sample size than the other techniques.

EXPERIMENTAL PROCEDURE

Scanning Electron Microscope/Energy Dispersive X-Ray Spectrometer

Samples of historic silks were prepared by mounting a 0.5 square cm. piece of fabric on a carbon disc. The disc was first coated with carbon for metal analysis; to produce clearer photographs, the samples were later coated with gold. Using the SEM, the silk fiber in the new silk and historic silk samples were magnified 2000 times, photographed and compared for surface details. The EDS probe was then used to analyze metals on each sample and the results recorded by a computer printout. EDS analyzes concentrations of elements approximately 7 microns deep, (which would be about half way through the fiber) and quantifies the percentage of metal compared to the other metals present on the fiber. While SEM/EDS identified elements, it was also necessary to quantitatively determine the percentage of each metal in relation to the silk fiber, i.e. the amount of the weighting agent. Therefore, another analytical tool, Neutron Activation Analysis, which could give exact quantities of metals in parts per million, was also used to document the presence of metals on samples identified as containing metals by the SEM. Those samples which did not show the presence of metals were not further analyzed.

Neutron Activation Analysis

Twenty four of the original 34 historic samples and a new silk sample were chosen for NAA based on the results of the SEM analysis. The sample of silk, about a one cm. square fabric, was placed in a 0.2 ml. polyethylene vial which had been cleaned with methanol. The mass of each sample was determined and the vial sealed by melting the sides of the cap to the vial. Each specimen was placed in the reactor three times: the first

and second insertions were for 3 minutes at a reactor power of 100 kw., the last exposure was 45 minutes at 225 kw. The samples were then brought to the detector and the gamma ray spectra collected for 400 seconds and recorded on magnetic tape. The half life of each element was recorded and compared to a standard for identification.

Inductively Coupled Plasma Emission Spectrometry

Based on the two tests presented above, 11 samples were then prepared for ICP analysis. One gram of sample is usually dissolved in 50 ml of aqueous acidic solution. However, problems were encountered when the weighted silk samples did not readily dissolve in either acid, chlorine bleach or oxidizing agents. The samples were prepared for analysis by digesting in perchloric acid and analyzed by emission spectrography. Inductively coupled plasma functions by exciting atoms to higher energy electronic states using a gas stream injected into an argon plasma generated by a radio-frequency generator. The procedure, like Neutron Activation, pinpoints all metals present on the substrate.

RESULTS

Visual Examination.

Several photographs of sample fabrics which are visibly deteriorated are shown in Figures 2-11. These include 3 black silks: a dress from 1850, a bodice from 1891 and a cape from 1896 and 2 light colored silks: a bodice from 1898 and a coat lining from 1906. Figures 2, 4, 8 and 10 show visible deterioration on the fabric surface, while figures 3, 5, 7, 9, and 11 show fiber deterioration in the same samples taken with the SEM.

Scanning Electron Microscope/Energy Dispersive X-Ray Spectrometer

The Scanning Electron Microscope (SEM) was used to photograph individual silk fibers magnified up to 2000 times. Unlike the smooth fibers of new silk (figure 1), the SEM micrographs of most of the historic silks show some type of deterioration, even when the garment itself appears to be in fairly good condition. However, the deteriorated fabric has an underlying deteriorated fiber as seen in the comparison of fabric and fiber micrographs. An 1850 black dress with slit fabric (figure 2), at the microscopic level looks corroded (figure 3). The 1891 black bodice fabric is slit in all directions (figure 4) and the SEM micrograph show cracked and misshapen fibers (figure 5). An 1896 black cape fabric (figure 6) appears to only be deteriorating in the weft direction. The SEM micrograph (figure 7) confirms that the weft fiber is deteriorated while the warp looks to be in good condition. This may be a case where only the weft was weighted rather than the entire fabric. Light colored fabrics also show deterioration. An 1898 pink fabric is broken at the microscopic level (figure 8, magnified 100x) as is the fiber itself (figure 9). Shredding is also evident both on the surface and at the microscopic level of the 1906 beige lining fabric shown in figures 10 and 11.

These photographs indicate that physical damage is taking place at the microscopic level resulting in a slowly deteriorating condition. Of the 35 samples observed, 20 or 57% show fiber damage on the microscopic level similar to one of the conditions presented above.

The x-ray equipment, EDXS probe, was used to determine the elements present on the surface of the silk. As expected, tin-silicate and iron were found in larger quantities than other metals. Of the 35 samples, 18 were found to contain tin and 8 iron. Other metals detected included aluminum, chromium, titanium, zinc and zirconium (Table 2).

Neutron Activation Analysis and Inductively Coupled Plasma

Neutron Activation Analysis (NAA) is a sensitive technique which detects all elements present except those with extremely short half-lives (such as lead) and records the amounts in parts per million. Two samples of new silk were also analyzed for comparison. This study, like other NAA studies made several assumptions linking element concentration to element function to interpret the concentration data in terms of the practical roles that the elements might play in the historic silk textiles. The roles of the elements are as: weighting agents, dye mordants and foreign contaminants. This study assumed that elements used as weighting agents would be present in concentrations exceeding 10,000 ppm, elements used as dye mordants would be present in concentrations between 1000 and 9999 ppm and elements detected at concentrations less than 1000 would be present as foreign contaminants. One study also showed that silk fabrics weighted with tin in excess of 30,000 ppm showed marked deterioration.²⁰ The historic silks analyzed here contain quantities of tin up to 77,000ppm and iron up to 35,000ppm depending on the color of the sample. The light or colored silks contained tin while black silk contained iron. Of the 24 samples, tin was detected on 22 samples and 18 contained iron either alone or in combination. There seems to be a correlation between metals present in the fiber and surface condition. Twenty two samples contained over 10,000 ppm of metals (tin or iron) and 20 of those samples had been visually identified as having a deteriorated surface condition. (Table 1). Dark colored samples which were most deteriorated contained over 10,000 ppm of iron or a combination of tin and iron. Deteriorated light or colored fabrics contained more than 20,000 ppm of tin. All three of the black fabrics in

figure 2-7 have concentrations of iron from 16,000 to 29,000 ppm. The 1891 sample (figures 4,5) has a tin concentration of 29,000 ppm in addition to the iron. The pink fabric (figures 8,9) contains 59,000 ppm of tin while the beige fabric (figures 10, 11) contains 75,000. (Table 2.)

Some elements, potassium, sodium (up to 25,000ppm), were present in all samples and appear to be a portion of the constituent fiber. Barium, a known delustering agent for silk was also present in all samples in quantities ranging from 2-100ppm. Other elements present many samples in quantities from 10-1000ppm which could be considered as contaminants were: arsenic, gold, rubidium, lead, zinc and zirconium.

The presence of arsenic in many of the historic samples raised some concern. The amount of arsenic varies among the samples, but significant quantities (up to 500 parts per million) were found in over half the historic samples while no arsenic was found on the new silk. There are two possible explanations for the presence of arsenic in the historic samples. Early museum practices included the application of arsenic as a pest control. This was especially true of natural history museums and presents a problem in those museums today.²¹ Another explanation is that arsenic is present as lead arsenate, a patented weighting agent. Since lead is an element with a very short half life, it could not be confirmed with either the SEM/EDS or NAA tests. However, ICP which is used in soil and plant analysis did establish the presence of quantities of lead (up to 500 parts per million) in many of the silk samples. There are many studies which have established the danger of ingesting lead and arsenic; levels of arsenic greater than 100 ppm and lead levels greater than 500 ppm are considered dangerous in soils.²² Further research, outside the scope of

this study, is necessary to understand if lead and arsenic present a danger due to skin contact.

SUMMARY AND CONCLUSIONS

Characterization and analysis of historic silks indicates that the problem of weighted silk is more complex than originally expected. The close range photographs of the silk fabric documents deterioration and damage. The black silk and very thin lining silks appear to be the most damaged showing slits in the fabric. The use of the scanning electron microscopy has revealed deterioration even in samples which appear to be in good condition. The samples which show cracked and shredded fibers at the microscopic level also contained either tin or iron or both. Neutron Activation Analysis and Inductively Coupled Plasma documented the concentration of metals present on the silks. Metals in large enough quantities to act as weighting agents (above 10,000 ppm) seem to correspond to surface and microscopic damage. However, not only are the metal oxides destroying the silk fabric, but they may also present a threat to those who handle them. The discovery of both arsenic and lead in over half the samples indicates that safe handling procedures should be developed for these materials.

Since the goal of a museum is to preserve objects from the past, the work of preserving textiles in the museum environment is becoming increasingly important. The question of how to care for weighted silk costumes is significant to not only large collecting institutions, but also to small historical societies with donated wedding dresses. The analysis of the weighting agents present on the historic samples has led to some disturbing findings for the museum community. Museum professionals and

the academic community need to work together to find solutions to textile conservation problems. The information in this study could aid in the understanding of the mechanisms of the deterioration of weighted silk and may eventually provide practical information for the museum professional.

ACKNOWLEDGEMENTS

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The presence of potentially harmful metals on weighted silk may present a problem in the museum environment. When handling weighted silk, good personal and laboratory hygiene is essential; the use of light rubber or plastic gloves and protective clothing is strongly recommended and a dust mask should be worn when working with any specimens which are dusting. The workspace should be well ventilated and, if possible, a fume hood should be used. Any questions about possible contamination should be directed to the local Occupational Health and Safety Organization (OSHA) office.

TABLE 1
HISTORIC SILK SAMPLES

Catalog#	DATE	GARMENT	COLOR	FABRIC	CONDITION	SEM	ELEMENTS
1	1850s	pelarine	black	silk	good	X	As,Co,Cr,Fe,Sn
2	1850s	cape-German	black	silk	slit		As,Cd,Fe,Pb,Zn
3	1856	dress	black	taffeta	rips,slits		As,Au,Fe,Pb,Zn
4	1865	bodice,skirt	green/brown	taffeta	holes	X	Fe
5	1870	polonaise	green	taffeta/sheer	sheer, holes		S,Zn,Si
6	1880	cape	white	satln	good		As,Cr,Fe,Sn,Zn
7	1880	lining cape*6	red	silk	silt	X	Al,As,Fe,Sn,Zn
8	1885	jacket	ivory	satln/silk	stained	X	S,Si
9	1891	bodice	wine/tan	velvet/silk	ripped		Sn,Cl
10	1891	bodice	black	silk/velvet	lining slit	X	As,Fe,Pb,Sn,Zn
11	1892	bodice	brown/print	wool/silk	holes		S,Fe,Zn
12	1896	cape	black	silk twill	ripped	X	As,Au,Cr,Pb,Sn
13	1898	bodice/skirt	black/blue	cotton-silk	rips		Al,As,Fe,Sn,Zn
14	1898	bodice	pink	satln	ripped	X	Al,As,Sn,Zn
15	1898	bodice	purple/pink	velvet/silk	lining slit	X	As,Fe,Pb,Sn,Zn
16	1900	bodice/skirt	white	satln	dirt/tears		As,Fe,Pb,Sn,Zn
17	1900	bodice	red/black	silk/lace	lace rips	X	S,Si
18	1900	part dress	black	silk/lace	good		As,Fe,Pb,Sn,Zn
19	1900	bodice/skirt	ivory	cotton/silk	lining slit		S,Si
20	1901	bodice	black	silk	ripped	X	As,Fe,Pb,Sn,Zn
21	1902	weddingdress	ivory	satln	scraps	X	As,Au,Fe,Pb,Sn
22	1903	underskirt	black	taffeta	slits,holes		As,Fe,Zn,Zr
23	1906	coatlining	beige	satln	scraps	X	As,Fe,Sn,Zn,Zr
24	1910	skirt	black	silk file	ripped		As,Fe,Pb,Sn,Zn
25	1913	bodice	black	silk	slit	X	As,Cr,Fe,Sn,Zn
26	1914	dress,slip	white/blue	voile/silk	silk ripped		As,Cr,Zn,Zr
27	1915	bodice	purple/black	silk/lace	good		As,Fe,Pb,Sn,Zn
28	1915	bodice	brown/beige	lace/silk	torn		As,Cr,Fe,Sn,Zn
29	1924	dress	yellow	silk/chiffon	silk slit	X	As,Fe,Pb,Sn,Zn
30	1925	dress-slip	printed	silk	holes		Cl,Ca
31	1927	bodice	black	satln	good		Sn,Si
32	1930	bodice	burgundy	lace/silk	good		Al,As,Sn
33	1930	dress	black	bemberg	holes		Si,Fe,Sn
34	1930	dress	blue	satln/net	slit	X	Ag,As,Pb,Sn,Zn
35		new silk	white	TestFabric		X	Br,Cr

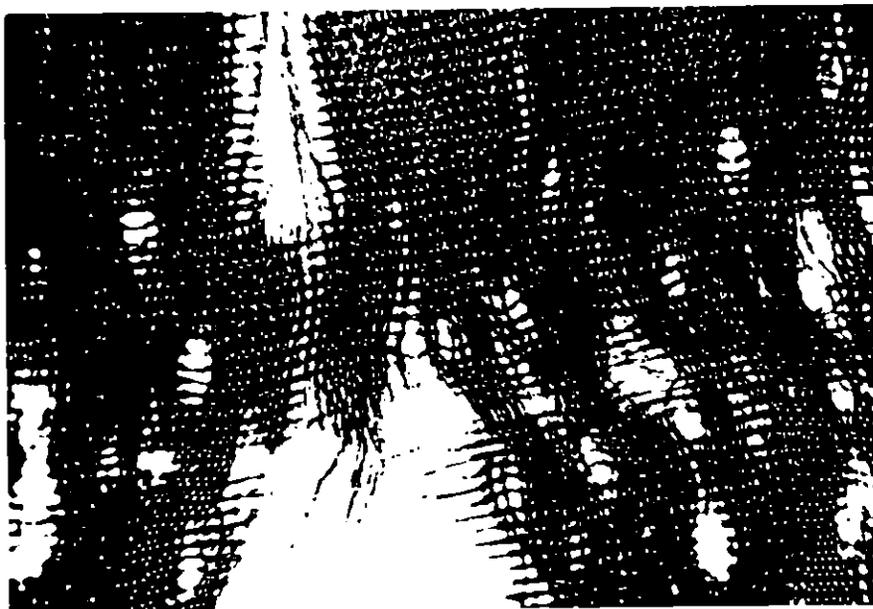
**TABLE 2
ELEMENTAL ANALYSIS**

SAMPLE DATE	GARMENT	COLOR	METHOD	ELEMENT CONCENTRATION PPM	
1	1850	pelarine	black	NAA	As-22;Fe-21,840;Rb-27.4;Sn-3,950;Zn-274;Zr-91
2	1850	cape	black	NAA	Au-22; Fe-29,570; Sn-3,702; Zn-285; Zr-42
				ICP	As-273; Pb-496
3	1856	dress	black	NAA	Fe-31,550; Sn-3,948; Zn-85; Zr-81
				ICP	As-226; Pb-826
4	1865	waist	green/brown	SEM	Ba, Na, K, Si, Fe (no quantative data with SEM)
5	1870	polonaise	green	SEM	Ba, Na, K, Si, Zn (no quantative data with SEM)
6	1880	cape	ivory	NAA	Fe-279;Sn-23,760;Zn-62;Zr-36
7	1880	cape lining	red	NAA	As*20.5; Fe-243; Sn-75,010;Zn-40.4;Zr-36.6
8	1885	jacket	ivory	SEM	Ba, Na, K, Si (no quantative data with SEM)
9	1891	waist	wlne/tan	SEM	Ba, Na, K, Si, Zn (no quantative data with SEM)
10	1891	waist	black	NAA	Fe-16,579; Sn-29,160 ;Zn-66; Zr-31
				ICP	As-505; Pb-118
11	1892	waist	brown print	SEM	Ba, Na, K, Si, Zn (no quantative data with SEM)
12	1896	cape	black	NAA	Au-13;Cr-11;Fe-19,790;Rb-103;Sn-9,741;Zn-218;Zr-81
13	1898	skirt	black/blue	NAA	Fe-9,753;Sn-2,637;Zn-177.3;Zr-31.6
14	1898	bodice	pink	NAA	Fe-139; Sn-59,000; Zn-44; Zr-32
				ICP	As-37; Pb-40
15	1898	waist	purple/pink	NAA	As-24; Fe-179; Sn-56,840; Sr-42; Zn-244; Zr-28
16	1900	waist	red/black	SEM	Ba, Na, K, Si (no quantative data with SEM)
17	1900	waist/skirt	white	NAA	Fe-163; Sn-26,490; Zn-168; Zr-21
				ICP	As-483; Pb-103
18	1900	dress	black	NAA	Fe-439; Sn-51,230 ;Zn-148; Zr-47
				ICP	As-334; Pb-379
19	1900	waist, skirt	ivory	SEM	Ba, Na, K, Si, Zn (no quantative data with SEM)
20	1901	bodice	black	NAA	Au-16; Fe-32,780; Sn-3,422; Zn-109; Zr-60
				ICP	As-440; Pb-50
21	1902	weddingdress	ivory	NAA	As-64;Fe-177;Sn-77,790;Zn-115;Zr-14
22	1903	underskirt	black	NAA	Fe-13,090;Rb-71.52 Sn-30,620;Zn-236.4;Zr-61.5
23	1906	llning	beige	NAA	As-57;Fe-130;Sb-10;Sn-75,320; Sr-45;Zn-30;Zr-410
24	1910	skirt	black	NAA	Fe-221;Rb-27.4;Sn-1,757;Zn-56;Zr-104
25	1913	bodice	black	NAA	Au-10;Cr-10;Fe-37,520;Rb-69;Sn-18,360;Zn-250;Zr-74
26	1914	skirt	white/blue	NAA	Fe-284.9;Sn-50,410;Zn-167.8;Zr-72.5
27	1915	waist	purple	NAA	Fe-205.3; Sn-68,570; Zn-87; Zr-87
				ICP	As-88.3; Pb-98
28	1915	waist	brown/beige	NAA	As-98;Au-23;Fe-237;Rb-103;Sn-46,305;Zn-297;Zr-101
29	1924	dress	yellow	NAA	Fe-189;Sn-52,790;Zn-74;Zr-246
30	1925	dress/slip	ivory print	SEM	Ba, Na, K, Si (no quantative data with SEM)
31	1927	bodice	black	SEM	Ba, Na, K, Si (no quantative data with SEM)
32	1930	bodice	burgundy	NAA	Fe-225;Sn-73,910;Zn-128;Zr-202
33	1930	dress	black	SEM	Ba, Na, K, Si (no quantative data with SEM)
34	1930	dress	blue	NAA	Fe-221; Sn-63,030; Zn-230; Zr-286
				ICP	As-223; Pb-177
35	new	Testfabric	white	NAA	Fe-188; Sn-550 Zn-8; Zr-3
				ICP	As-9; Pb-3

**FIGURE 1
NEW SILK**



**FIGURE 2
1850
Black
Fabric**



**FIGURE 3
1850
SEM
Fiber**

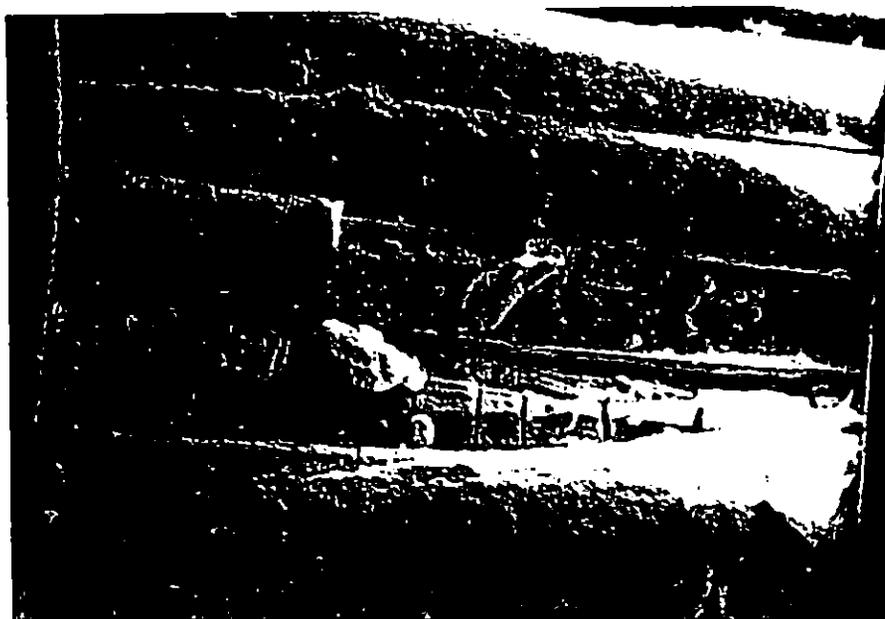


FIGURE 4 1891 Black Fabric



FIGURE 5 1891 SEM Fiber

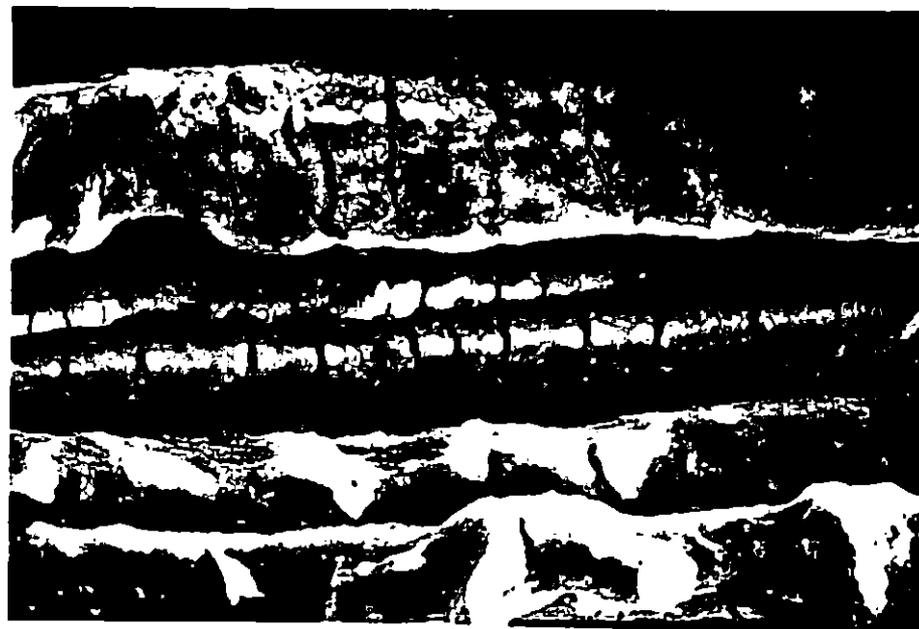


FIGURE 6 1896 Black Fabric



FIGURE 7 1896 SEM Fiber



FIGURE 8 1898 Pink Fabric

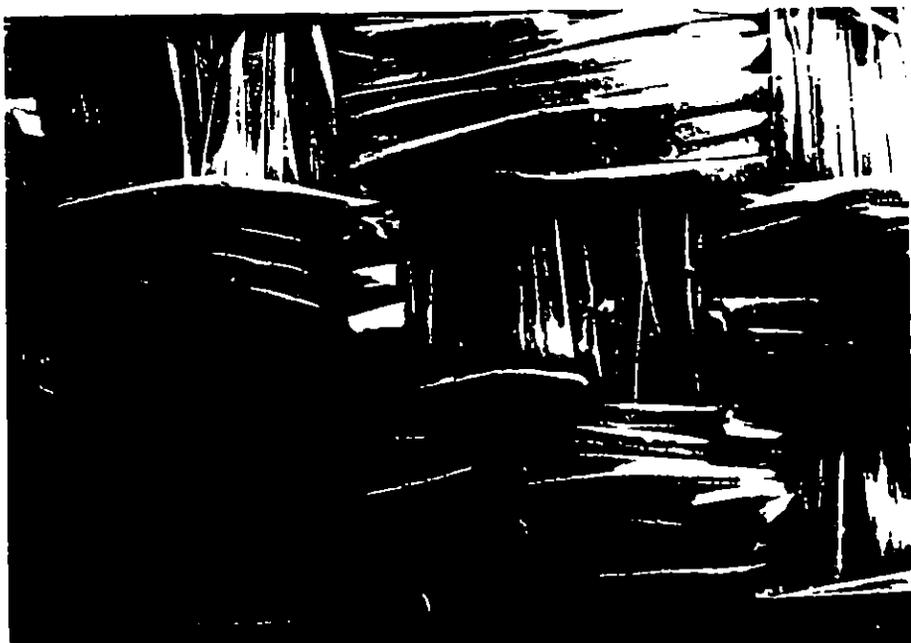


FIGURE 9 1898 SEM Fiber



FIGURE 10 1906 Beige Fabric



FIGURE 11 1906 SEM Fiber

