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THE DOCUMENTATION OF A 19th CENTURY ALBUMEN PRINT OF MOUNT ARAFAT BY THE EGYPTIAN PHOTOGRAPHER MUHAMMAD SADIQ BEY

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Abstract

Muhammad Sadiq Bey, an Egyptian army engineer and surveyor and the treasurer of the Egyptian Hajj caravan, was the first one to photographically document Mecca, Madina, and the Hajj. This paper presents the documentation of a 19th-century albumen print of Mount Arafat captured by Sadiq Bey. Albumen prints are extremely unstable compared to other silver-based photographs. The photograph is fixed to a poor-quality secondary support and is preserved in a wood frame. Several examination and analysis techniques were employed for condition evaluation, including visual inspection, stereomicroscopy, ultraviolet (UV) and infrared (IR) imaging, scanning electron microscopy coupled with energy dispersive x-ray fluorescence spectrometry (SEM-EDS), pH value measurement, Fourier transform infrared spectroscopy (FTIR), and microbiological studies. Visual and microscopic inspection revealed the yellowing and flaking of the albumen binder layer, the fading and discoloration of the image silver, and the yellowing and embrittlement of the secondary support. The photograph suffered from microbiological attack and insect attack (i.e., Anthrenus pimpinellae larva). IR imaging showed that the image has been retouched. SEM examination revealed the presence of a network of micro-cracks and fungal spores. EDS analysis showed the presence of silver sulfide, which is responsible for image discoloration. The average pH value of the secondary support is 4.9. FTIR revealed the severe degradation of the albumen binder on the left side of the image compared to the right side, and it also showed that the secondary support suffers from oxidation as indicated by the formation of carbonyl groups. Aspergillus niger and Emericella nidulans were isolated from the examined albumen print; nevertheless, only A. niger seemed to be the causative agent of biodeterioration. A. niger produces organic acid that is partially responsible for the decreased pH value of the photograph and secondary support.

Keywords*: Muhammad Sadiq Bey; Damaged albumen print; Stereomicroscope; UV and IR imaging; SEM-EDS; pH value measurement; FTIR; Microbiological studies*

Introduction

Photographs are powerful visual resources that precisely document significant moments, individuals, values, cultures, expressions, landscapes, social development, and ways of life throughout history [1]. From the mid-19th century onward, photography has greatly contributed to the preservation of the history of the hajj since it was possible for the first time ever to accurately and realistically document the pilgrimage, the pilgrims, and the holy cities by producing reproducible photographic images [2].

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Muhammad Sadiq Bey (1832–1902), an Egyptian army engineer and surveyor and the treasurer of the Egyptian Hajj caravan (Fig. 1), having visited the Hijaz numerous times [3, 4], was the first one to photographically document Mecca (Fig. 2), Medina, and the Hajj [3]. Sadiq Bey travelled to Saudi Arabia in 1861 with the so-called "wet-plate collodion camera" [2] to produce his first photograph using the wet collodion process, a photographing technique that was invented in the 1850s [3]. The wet-collodion-on-glass negatives (i.e., the wet collodion process), invented by Frederick Scott Archer, an English photographer and sculptor, were the first successful negative process, as the transparency of the glass produced a high resolution of detail in both the highlights and shadows of the resultant prints. It also had shorter exposure times compared to previous photographic processes (i.e., the daguerreotype and calotype). The resultant negatives were usually used to produce albumen prints [5]. Sadiq Bey's photographs were often signed and dated on the negative. His most significant photographs of Mecca, Madina, Arafat, and Mena were taken in 1880 and 1881 [3].

Fig. 1. Muhammad Sadiq Bey, the First Arab Photographer of the Holy Kaaba. Source: Guide of the Pilgrimage Through all the Routes to Mecca and Medina), authored and illustrated by Muhammad Sadiq Bey in 1896 and published by the government press, Bulaq, Cairo.

Fig. 2. Mecca (Saudi Arabia). The Mosque: The ceremonies around the Kabaa by Muhammad Sadiq Bey. Source: Victoria and Albert Museum, London, 2025 at: https://collections.vam.ac.uk/item/O1031120/the-mosque-the-ceremonies-and-photograph-bey-sadic/

Sadiq Bey's photographic achievements were recognized by both the Arab and European worlds, and in 1881, he won a gold medal at the Venice Geographical Exhibition. He published two important works: The Mash'al al-Mahmal (i.e., the Torch of the Mahmal) in 1881 and Dalil al-Hajj (i.e., the Guide to the Hajj) in 1896, both of which included his photographs and observations of his journeys (Fig. 3) [3].

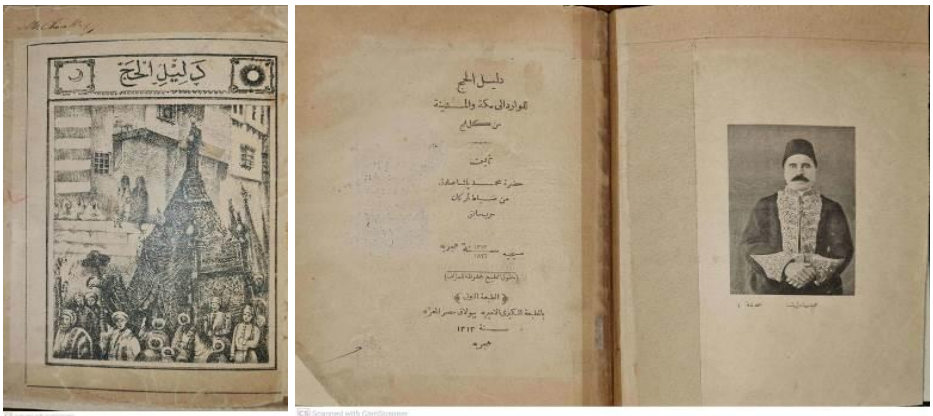

Fig. 3. Dalil Al-Hajj Li Al Warid Ila Makka Wa Al Medina Min Kulli Fajj (i.e., Guide of the Pilgrimage Through all the Routes to Mecca and Medina), authored and illustrated by Muhammad Sadiq Bey in 1896 and published by the government press, Bulaq, Cairo.

Albumen prints during the time of Sadiq Bey were produced by contact printing a wet collodion glass negative on a sheet of sensitized albumen photographic paper; therefore, the resultant albumen prints have the identical size of the camera-produced negatives. The albumen process, invented by Louis-Désiré Blanquart-Evrard, originally a French cloth merchant from Lille but later studied photography, in 1850, was the most common positive printing photographic process of the 19th century [6, 7]. It dominated for approximately 40 years yet survived into the late 1920s [6]. To prepare a sensitized albumen photographic paper, a sheet of rag paper was first coated with albumen, egg white, containing sodium chloride or ammonium chloride [8]. Then the coated paper was floated on a solution of silver nitrate to form silver halide crystals (i.e., the light-sensitive material) [9]. The role of the albumen (i.e., the binder) is to bind the light-sensitive silver halide salt to the paper substrate (i.e., the primary support) [10]. A contact printing frame was then used to obtain the image by placing the negative on the now light-sensitive paper [11]. After prolonged exposure to light, a printout image composed of small spherical silver grains known as photolytic silver (i.e., the final image material) is formed. After exposure and physical development, the image was toned, fixed in hypo, washed, and dried [12]. Gold toning was commonly used when toning albumen prints. Resultant images exhibit a shift of color toward darker-brown or violet-black tonalities [6].

Albumen prints have the following characteristics: a warm image tone, reddish-brown to purplish-brown; a semi-matte to glossy surface; paper fibers are visible under the binder; a thin primary support; and they commonly suffer from overall yellowing, fading, and a network of fine cracks [13]. Albumen prints prior to 1870 were usually less glossy than those made later by surface burnishing and varnishing. Most albumen prints were often affixed to cardboard mounts of varying sizes [10].

Albumen prints are extremely unstable compared to other silver-based photographs; this is due to the inherent instability of the image silver and albumen binder. Albumen prints have very small silver particles, ranging in size from 5 to 25 microns in diameter; accordingly, they expose more surface area and thus are extremely vulnerable to oxidation and chemical attack,

resulting in fading and yellowing [14]. Albumen drastically deteriorates and yellows due to the inherent characteristics of the egg white protein and its chemistry [15]. The characteristic yellowing of albumen prints has been linked to the Maillard reaction, which involves the free sugar in albumen combining with proteins and/or amino acids, forming double bonds (i.e., a highly colored conjugated compound) [14, 16].

Albumen prints are prone to deterioration and/or degradation by numerous factors such as natural aging, poor processing (i.e., exhausted or insufficient fixing bath, incorrect washing, and insufficient toning treatment), inappropriate temperature and relative humidity levels, inappropriate light levels, biological threats, pollutants, inappropriate storage and display, mishandling and misuse, disasters, and inappropriate conservation treatments [17-19].

Image silver is very sensitive to pollutants, particularly oxidizing agents, since nearly all image decay forms begin with oxidation [20]. Forms of image silver decay include fading, silver mirroring, and discoloration [14, 21]. Oxidation also plays a role in paper degradation [22]. Oxidation of cellulose, the main component of paper, leads to the formation of aldehydes, ketones, and carboxylic acids, which cause discoloration (i.e., yellowing); it also causes the breakage of the glycosidic bonds, which decreases the mechanical strength of paper [23]. Albumen contains sulfur. Upon oxidation, sulfur forms a pair of double bonds, which leads to yellowing [16]. Albumen has a strong tendency to bind to silver ions; thus, during processing, colorless silver-albuminate may be formed; these react with sulfiding compounds and form yellow silver sulfide, leading to yellowing and loss of detail in non-image (highlight) areas.

Fluctuating temperature and relative humidity cause the albumen binder to expand and contract; as a result, the image layer exhibits a characteristic network of fine cracks [14, 24].

Light oxidizes the benzene ring-containing amino acids in albumen, forming highly colored substances [14]. Oxidation, initiated by light, also discolors the paper [25].

Mold is another common cause of damage threatening the permanence of photographic collections. In the presence of favorable environmental conditions, albumen prints with their high organic content (i.e., cellulose and protein) and hygroscopic nature provide the culture medium necessary for mold growth [26]. The spores absorb water and grow rapidly, forming a mold colony. Fungal attack results in embrittlement and disfiguration of photographic materials and eventually the total destruction of the image by extracting carbon and nitrogen through an enzyme hydrolysis reaction [27]. Hydrolytic enzymes such as cellulase, xylanase, and pectinase can cause mechanical, chemical, and aesthetic damage to valuable documents [28]. Mold also produces colored materials, which stain the photograph [29]. Mounted photographs include hygroscopic adhesives that accelerate fungal attack [30].

Insects (e.g., silverfish, psocids, cockroaches, and beetles) and rodents (e.g., mice and rats) are another potential threat to photographic collections [31]. In addition to eating materials resulting in tunnels and holes, they also foul the materials with their droppings, which can result in local discoloration and fading of the image and staining of the recto and verso of the photograph [31, 32]. Moreover, they make nests that can be difficult to locate and remove [33].

Albumen prints are also prone to physical damage as a result of improper handling and misuse. Resultant forms of damage include fingerprint stains and mirroring, scratches, tears, creases, cracked corners, and missing parts [33]. Silver mirroring (i.e., mirroring) involves the oxidation of image silver to silver ions; these migrate to the surface where they react with environmental sulfur-based compounds, forming silver sulfide (Ag_2S). It appears as a bluish metallic sheen, giving the shadow areas an iridescent appearance, and in very severe cases, it can appear green, violet, or bronze in color [34]. Poor-quality mounts become acidic over time and can eventually lead to the acidification of the photograph, resulting in mechanical (i.e., embrittlement) and chemical damage (i.e., discoloration) [35]. Adhesives also become brittle and discolored [36].

Accumulations of solid particles (i.e., dust) can cause abrasion, while sticky dust (i.e., soot) may stain the surface [37].

Heat and humidity are the primary factors that govern the occurrence and rate of biological decay, chemical instability, and mechanical damage. High temperature and low relative humidity lead to desiccation, embrittlement, and distortion of paper, albumen, and adhesives. Short-term cycling of RH may cause edge peeling, flaking, or binder cracking. Wide fluctuations in relative humidity produce various forms of physical deterioration [38].

Wood frames were the most common display method, and while advantageous for the safeguarding of such valuable records, they do present many issues when used in an uncontrolled environmental condition since they are sensitive to their surrounding environment, particularly changes in temperature and relative humidity and biological threats [39].

Deteriorated albumen prints require specific conservation treatments that respect their fragile and complex nature. This paper studies a severely damaged albumen print of Mount Arafat captured by Muhammad Sadiq Bey in the 19th century. This framed photograph suffers from various forms of damage, particularly biological damage. Several examination and analysis techniques were employed for the condition evaluation process, including visual inspection, stereomicroscopy, UV and IR imaging, scanning electron microscopy coupled with energy dispersive x-ray fluorescence spectrometry (SEM-EDS), pH value measurement, Fourier transform infrared spectroscopy (FTIR), and microbiological studies. Based on the obtained results, a suitable conservation plan was developed.

Photograph description and condition assessment

Materials

Description of the photograph

The photograph is of Mount Arafat, and it is preserved in a wood frame (Fig. 4). Mount Arafat (Fig. 5), also known as Jabal ar-Rahma (i.e., the Mount of Mercy), is a granite hill located in the southeast of Mecca (i.e., Makkah), Saudi Arabia.

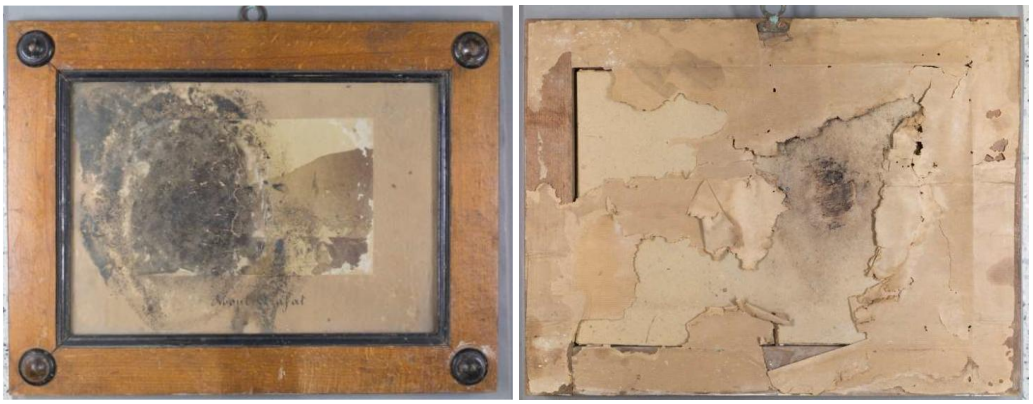

Fig. 4. Muhammad Sadiq Bey's photograph of Mount Arafat preserved in a wood frame. The figure shows the recto and verso of the framed photograph

To be precise, it is situated between Taif and Makkah, at 10km from Mina, 6km from Muzdalifah, and 22km from Makkah. The hill and day of Arafat hold great significance in Islam; it is an essential part of Hajj. For Muslims, it represents the sum and substance of Hajj, and as said by Prophet Muhammad PBUH, "Hajj is Arafat" (Al-Hakim, Al-Mustadrak). On the 9th of Dhul Hijjah, also known as the Day of Arafah, the pilgrims leave Mina for Mount Arafat, where the combinational prayer of Dhuhr and Asr is prayed; later, they spend the entire day on Mount Arafat, reciting the Quran and making dua (i.e., supplication), invoking Allah SWT to forgive their sins and

requesting Allah SWT to answer their prayers and shower his blessings over them. It is said that on the Day of Arafah, Allah SWT descends to the sky and says to the angels, “My slaves have come to Me, rough and disheveled, coming from every distant valley hoping for My mercy, so if your sins were equivalent to the amount of a grain of sand or a drop of rain or like the foam on the sea, I will forgive them. So go forth, My slaves! Having forgiveness for what or who you have interceded for” (Tabarani). It is also mentioned in the holy Quran, and it is where Prophet Muhammad PBUH delivered the last sermon to the Muslims who accompanied him for the Farewell Pilgrimage towards the end of his life. Mount Arafat has a small tent city (Fig. 6) [40-42].

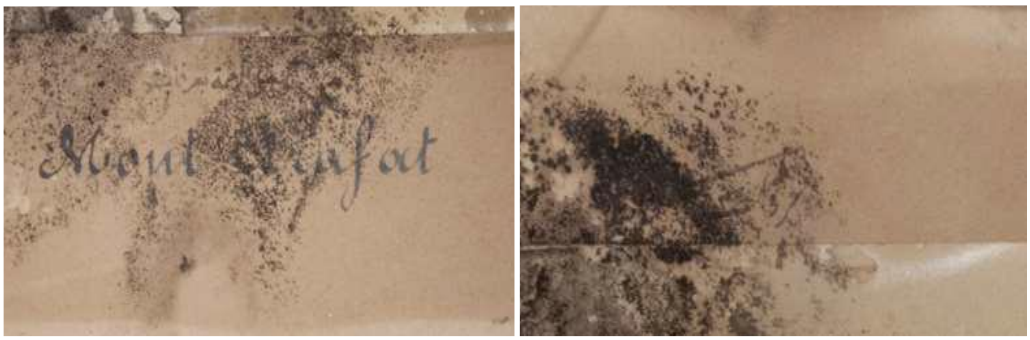

Fig. 5. The photographed site (i.e., Mount Arafat)

Fig. 6. The tents at Mount Arafat

The image was captured by Muhammed Sadiq Bey during Hajj in 1297 AH (i.e., 1880 AD), as signed and dated on the photograph. It is a monochrome photographic print with a warm continuous tone (Fig. 7). The image shows retouched areas (Fig. 8). The photograph is mounted on a poor-quality secondary support (Fig. 4). The size of the image is 21.7×14.3cm, and the size of the secondary support is 34.5×24.5cm. The photograph was found stored at the Egyptian Geographic Society, which was established by a decree of Khedive Ismail Pasha on May 19, 1875. The storage space was found to suffer from poor ventilation, uncontrolled environmental conditions, and high relative humidity.

Fig. 7. Muhammad Sadiq Bey's signature in Arabic and English.
The image also shows the date the photograph was captured in 1297 AH (i.e., 1880 AD)

Fig. 8. A retouched area of the photograph

Methods

The following examination and analytical techniques were used to evaluate the condition of the photograph and develop a proper conservation plan.

Visual inspection and Stereomicroscope examination

Visual inspection is one of the most effective means of examining photographs. The following aspects were documented via visual inspection: presentation method, mounting method, image tone, surface characteristics (i.e., sheen), support material, damage forms, date, and photographer. The stereomicroscope used to document the surface characteristics of the print and the damage forms is a ZEISS SteREO Discovery.V20 microscope with motorized 20× zoom.

Ultraviolet and infrared imaging

UV examination was carried out using UV lamp model VL-4.LC from Vilber Lourmat, France. Lamp specification: 1×4-watt tube, wavelength 365nm, intensity at 15cm (uW/cm^2) 350.

IR imaging was carried out using a Philips Infrared Lamp, model R95 IR 100W E27 220-240V Red HG 1CT/20, and a Sony ILCE5000 modified to shoot with IR light.

SEM/EDS

Microscopic examination and analysis were performed using a scanning electron microscope, Model Quanta FEG 250 equipped with an EDS unit, with an accelerating voltage of 20kV. The sample was not gold coated. This analysis was carried out at the National Research Center (NRC), Giza, Egypt.

pH value measurements

The pH values were measured according to ASTM D778-97(2002) Standard Test Methods for Hydrogen Ion Concentration (pH) of Paper Extracts, the cold-extraction method. Measurements were carried out in triplicate using an Adwa Pocket pH Meter AD12, made in Romania. 1.0g of

sample from the verso of the secondary support was placed into 70mL of distilled water for a period of 1 hour. The measurements were carried out at the Manuscripts Conservation Laboratory, Conservation Department, Faculty of Archaeology, Cairo University, Egypt.

FTIR

The spectra were obtained by using a Nicolet 380 FT-IR Spectrometer in the frequency range of 4000-400cm^{-1}, in transmission mode. Samples were prepared using the KBr pellet technique, where the solid sample was grinded with potassium bromide (KBr) and great pressure was applied to press it into a disc. The analysis was performed at the National Institute for Standards (NIS), Giza, Egypt.

Microbiological studies

Since there is a major microbiological infection covering almost half of the photographic surface and the secondary support, microbiological studies were carried out at the Grand Egyptian Museum Microbiology Laboratory to isolate and identify existent species (Fig. 9). Fungal and bacterial isolation was performed from a 1.0cm^2 surface of albumen print and the secondary support using the cotton swab technique [43]. Fungi were isolated on different media: potato-dextrose agar (PDA) "Nissui", cellulose agar (CA) [44], (10.0g cellulose, 2.0g $NaNO_3$, 1.0g KH_2PO_4, 0.5g KCl, 0.5g $MgSO_4 \cdot 7H_2O$, 0.01g $FeSO_4 \cdot 7H_2O$, 20.0g agar, and 1.0L distilled water), and Malt extract agar (MEA) [45] (20.0g malt extract, 1.0g peptone, 20.0g glucose, 20.0g agar, and 1.0L distilled water). Media were supplemented with chloramphenicol (100mg/L) to inhibit bacterial growth. After 7-14 days of cultivation at 28°C, the growing fungal colonies were identified according to *K.B. Raper and D.I. Funnel* [46] and *K.H. Domsch et al.* [47]. Bacteria were isolated on Nutrient agar (NA) medium "Nissui." Fungal and bacterial concentration was expressed as colony-forming units per square meter (CFU. cm^{-2}). Mechanical treatment using a vacuum cleaner [48] was conducted, and the isolation was repeated after storing the object in a controlled environment.

Fig. 9. Collecting samples from infected areas using the swab sampling technique

The passive sedimentation method described by Omeliansky (1940) [49] was applied for sampling of aeromycobiota. A Petri dish containing PDA medium was placed open near the photograph during the wiping process and was exposed for 30 min. After 7 days of cultivation at 28˚C, the fungal colonies were counted. The number of colony-forming units per cubic meter of air (CFU. m-3) was estimated according to Omelyansky's formula [50]:

$$N = 5a \times 104(b \cdot t)\text{-}1$$

where N is the number of (CFU. m^{-3}), **a** is the number of fungal colonies per Petri dish, **b** is the Petri dish surface (cm^2), and **t** is the exposure time (min.).

Results and discussion

Condition assessment

Visual inspection and stereomicroscope

The photographic process utilized to produce this image was found to be the albumen process (Fig. 10), as indicated by the warm brown image tone, the characteristic overall yellowing of albumen prints via visual inspection (Figs. 10 and 11), and the visible paper fibers under the binder (Fig. 12) [6, 13].

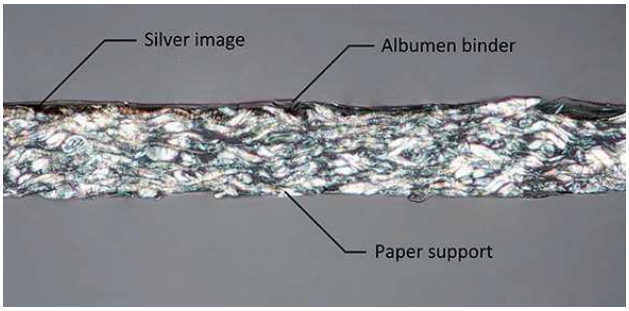

Fig. 10. The layer structure of an albumen print.
Image courtesy of Image Permanence Institute from www.graphicsatlas.org

Fig. 11. The warm image tone and the overall yellowing characteristic of albumen prints

Fig. 12. Stereomicroscopic image showing the paper fibers under the albumen binder at a magnification of 4.7×

The framed photograph was found to suffer from several forms of damage, which are listed in Table 1.

Table 1. Forms of damage found in the photograph

Location	Forms of damage
Image silver	Discoloration and fading
Binder	Dust, overall yellowing, cracking, flaking, fungal stains, fragility, and losses
Primary support: paper	Embrittlement and separation from the secondary support
Secondary support: paper	Embrittlement and yellowing due to increased acidity, and fungal stains
Frame	Dust, dirt, and corrosion of metal hanger

The photograph was kept in an uncontrolled storage area for a long period; this has led to the accumulation of dust and dirt on the frame and the photograph since the former was inadequately sealed. It has also allowed for the accumulation of moisture and detrimental gases, and as a result, the binder and the paper support have been aggressively attacked by a black mold (Figs. 13, 14, and 15), which has severely stained the photograph and weakened the binder, which has flaked and exhibits losses (Figs. 7 and 12) [10], while the image silver has suffered from discoloration and fading (Fig. 16).

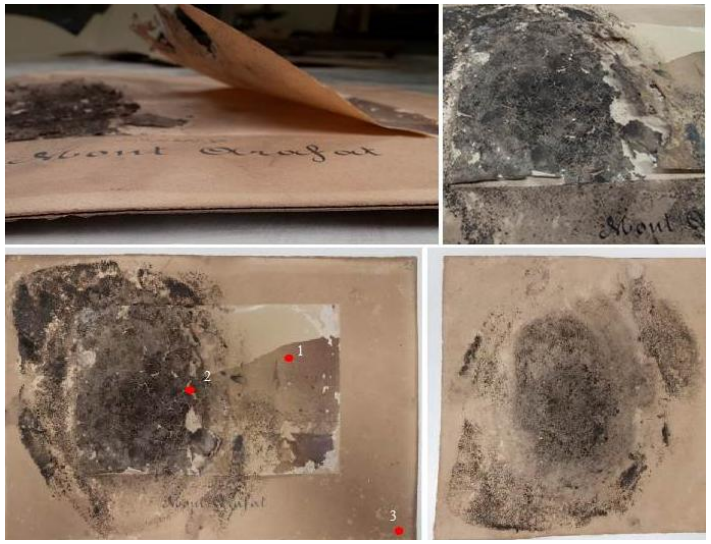

Fig. 13. The separation of the primary support from the mount (top, left); microbiological deterioration of the image and secondary support with black mold (top, right, and bottom). The red circles define the places where the FTIR spectra have been collected

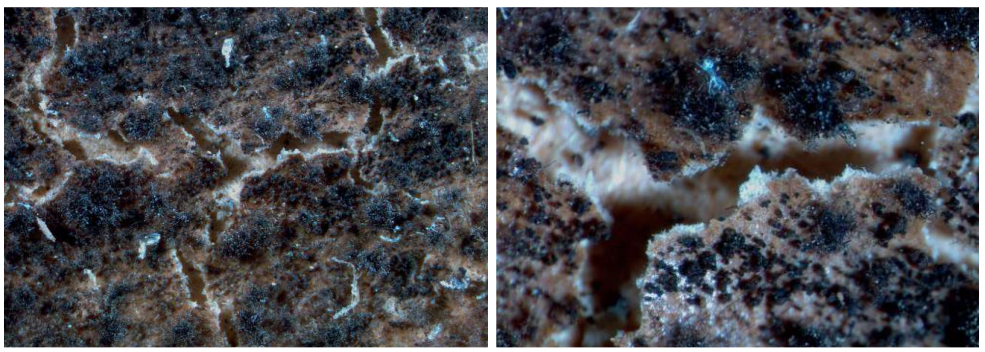

Fig. 14. Stereomicroscopic images of the photographic surface suffering from microbiological damage. Magnification: 22× (left) and 57× (right)

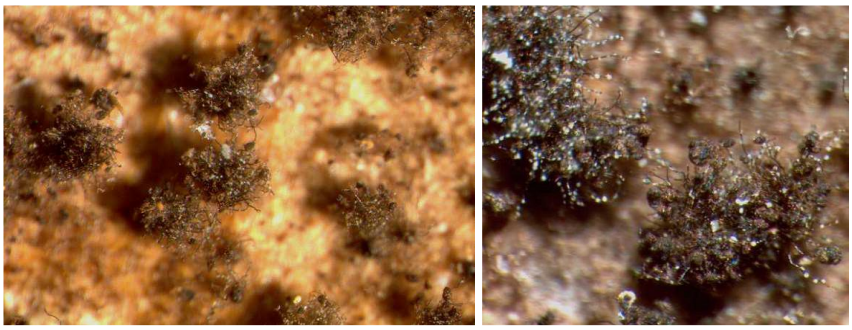

Fig. 15. Stereomicroscopic images of microbiological infection on the photographic surface. (70×)

Fig. 16. Stereomicroscopic image of silver image decay in the form of discoloration and fading

The damage caused by fungi is immense since they can cause mechanical, chemical, and aesthetic damage to photographic materials [51]. The fungal hyphae form a network of tunnels below the binder layer; fungi lead to staining due to mycelium growth and the release of colored metabolites [52]; and they consume organic components, causing it to become severely fragile. Albumen (i.e., the photographic binder) is more hygroscopic compared to paper, and its proteinous nature makes it very susceptible to fungal attack. Binder degradation by fungal growth is a serious problem since it causes the loss of the image, as shown in figures 12, 13, 14, and 15 [53].

Image silver in albumen prints typically exhibits yellowing of the highlights, loss of the lighter tones, and overall fading of the deepest tones. As previously mentioned, the image structure of albumen prints makes them very sensitive to oxidative attack and sulfiding. The sources of oxidants are many. Upon oxidation, image silver particles (Ag^0) are stripped of electrons and converted to invisible silver ions (Ag^+). Silver ions can migrate within the photographic binder [21, 17]. Migrating silver ions either remain as invisible silver ions, disperse into very small silver particles, or react with a sulfur compound to form yellow/brown silver sulfide. Depending on the size of the resulting silver or silver sulfide particles, the image may fade (i.e., minute particles) or shift to more yellow (i.e., medium-sized particles) or brown tones (i.e., large particles) [21].

In albumen prints, during deterioration, silver ions end up as small particles in white areas, giving them a yellow discoloration and sometimes leading to fading [21, 17]. Silver-thiosulfate complexes, which are present in exhausted fixer baths, decompose to form silver sulfide, giving the image a yellowish-brown tone [18, 54]. Further exposure to poor conditions for a long period converts silver sulfide to silver sulfate, which is colorless, causing fading and detail loss. The

highlight areas of an image show this first [54]. Furthermore, residual processing chemicals contain sulfur (i.e., thiosulfate ions), and if the photograph is inadequately washed, they will react with the image silver particles to form silver sulfide, and eventually the image will discolor (i.e., may turn brown) [18]. In addition to faulty processing, other sources of sulfur include adhesives, poor-quality mounts, and air pollution [55].

The secondary support is very weak and is apparently acidic, as indicated by the brittle physical structure and the yellowing. In addition to oxidation, paper also undergoes degradation via acid-catalyzed hydrolysis. The hydrolysis involves the breakage of the β(1→4) bonds between particular D-glucose units. The shortening of the cellulose chain results in a loss of the mechanical strength of paper. It also produces -CHO groups that are susceptible to oxidation [22]. Oxidation forms aldehydes, ketones, and carboxylic acids (i.e., carbonyl groups), which lead to discoloration [23]. Acidity accelerates this hydrolytic reaction [56]. Sources of acidity include air pollution, poor-quality enclosures, the raw material itself (i.e., wood pulp), manufacturing additives (i.e., alum-rosin sizing), and deterioration products (e.g., carboxylic acid) [57]. Lignin present in poor-quality secondary supports is more susceptible to oxidation and hydrolysis compared to cellulose [58]. Upon degradation, lignin creates acidic compounds. These acids may transfer to the photographic material, causing embrittlement and discoloration (Fig. 12) [59]. "

Insects were visually detected after opening the frame package (Figs. 17 and 18). These creatures feed on the albumen binder, the paper supports, and the adhesive used to fix the photographic print to the mount. They also may be attracted to fungus growths [54]. The insect has been identified as *Anthrenus pimpinellae* in the larva stage (Fig. 18) [60]. *Anthrenus pimpinellae*, commonly known as the carpet beetle, is a species of *beetle* that belongs to the order Coleoptera and family Dermestidae. The larvae of many species of carpet beetles are covered with spear-headed hairs [61]. Their larvae may cause considerable damage to museum collections [62].

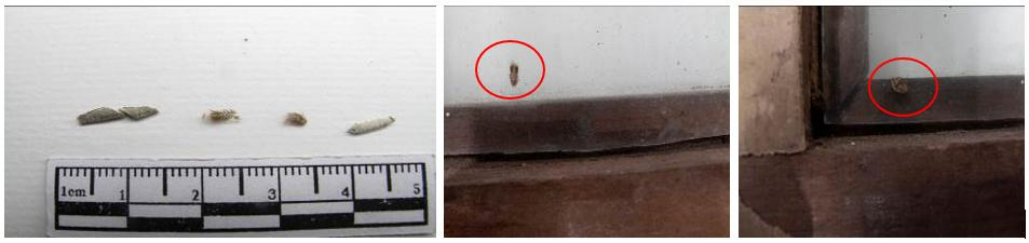

Fig. 17. Insects found inside the frame holding the photograph

Fig. 18. Stereomicroscopic view of the insect found inside the frame holding the photograph (left and center) and the *Anthrenus pimpinella*e larval case based on the collection at the Spencer Entomological Museum (right)

Ultraviolet and infrared imaging

Examination of the image under UV light was unuseful. On the other hand, IR light revealed the presence of a retouching medium (Fig. 19) [63].

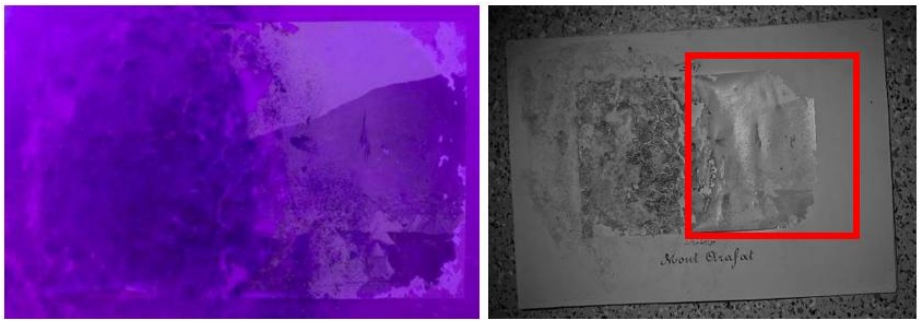

Fig. 19. Examination of the photograph under a UV lamp to investigate the surface (left) and under IR lamp to investigate the surface (right)

SEM/EDS

Examination using a scanning electron microscope revealed the presence of a network of micro-cracks on the surface of the photograph, which is a typical microscopic characteristic of albumen prints (Fig. 20) [6]. This occurs due to the several cycles of wetting and drying that take place during the manufacturing process as well as due to the fluctuation in temperature and relative humidity [6, 64]. The albumen binder's expansion rate is different from that of the primary support; it shrinks and curls, causing strain in the albumen layer, creating micro-cracks that have an average width of approximately 10µm [6]. SEM examination also reveals the presence of fungal spores (Fig. 21).

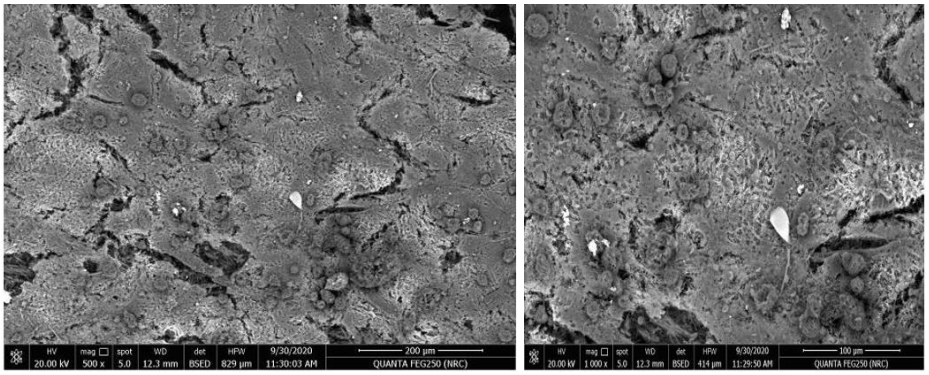

Fig. 20. Micrograph of the albumen print's surface showing microcracks at a magnification of 500× (left). The micrograph on the right shows fungal spores at a magnification of 1000×

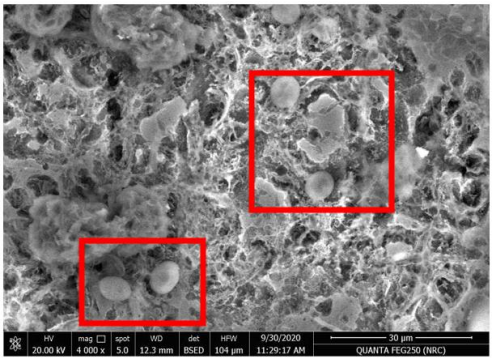

Fig. 21. Micrograph of the albumen print's surface showing fungal spores at a magnification of 4000× (left)

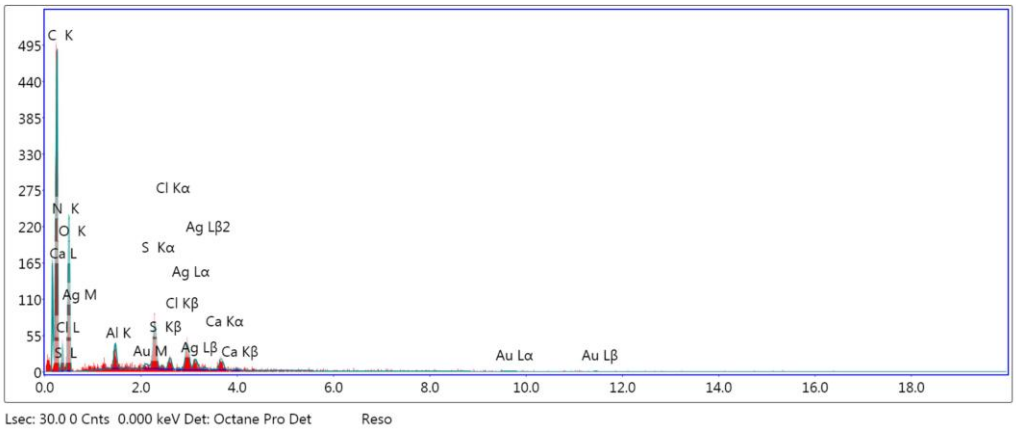

Fig. 22. EDS spectrum of the surface of the photograph

Table 2. EDS elemental analysis of the image side of the photograph

Element	Weight %	Atomic %	Net Int.	Error %
C K	39.47	49.1	46.92	9.68
N K	14.02	14.95	4.91	18.81
O K	35.16	32.84	32.65	12.85
AlK	1.13	0.62	8.03	14.02
S K	2.36	1.1	18.31	11.06
ClK	0.65	0.27	4.53	23.57
AgL	3.54	0.49	11.91	17.18
CaK	1.16	0.43	5.82	19.62
AuL	2.53	0.19	0.78	68.81

EDS elemental analysis shows the presence of silver (Ag) as the final image material [6] and gold (Au) and chloride (Cl), which reveals that the image was gold toned. Gold toning was carried out using a mixture of gold chloride and sodium thiosulfate (i.e., hypo) in the decade 1850-1860. However, this method had many drawbacks and was replaced by the separate toning technique, which involved using gold chloride, followed by fixing in hypo. This later technique deposited more gold, which contributed to the resistance of albumen prints to oxidative fading and the protection of the silver image from oxidizing gases [8]. The source of chloride may be a result of insufficient fixing, which causes residual silver halide (i.e., the light-sensitive material) to remain in the binder layer, leading to discoloration over time [33]. Sulfur is also detected, indicating the formation of silver sulfide; this explains the discoloration of the image (i.e., yellowing). Several elements related to paper manufacture, such as calcium, carbon, and aluminum, were also detected, suggesting the use of fillers [30]. Absence of barium (Ba) in the baryta layer, a layer composed of barium sulfate in gelatin, found in silver gelatin prints and collodion prints, confirms that the photographic process used to produce the image is the albumen process [6, 13, 21]. Results are shown in Figure 22 and Table 2.

pH value measurements

The average pH value for the secondary support was 4.9, indicating that it suffers from acidity; thus, it requires a deacidification treatment.

FTIR

The places where the spectra were collected are shown in figure 13. ATR-FTIR results show the presence of amide I and amide II bands characteristic of proteins (i.e., albumen and gelatin). The amide I corresponds to the vibrations of the C=O group with very minor contributions of the C-N groups and is located at ~1650cm^{-1}, while the amide II band originates from the in-plane N-H bending, along with both the C-N stretching vibrations and the C-C

stretching vibrations, and is located at ~1550cm^{-1} [6, 65, 66]. To differentiate between albumen and gelatin, one should inspect the spectral region between 1470 and 1250cm^{-1}. In albumen prints, two peaks of the same intensity are observed in this spectral region, while in gelatin prints, these two peaks differ in intensity [6]. The spectrum also reveals the presence of the N-H and hydrogen-bonded O-H stretching vibrational frequencies at 3280.04 cm^{-1}, the C-H stretching band at 2944.25cm^{-1}, and the C-O stretching band at 1036cm^{-1} [67, 68]. These are absorption bands of cellulose [69] (Fig. 23). As for the left side of the image, all previous bands have been detected. By comparing this side, which shows severe deterioration of the image layer, with the right side of the photograph, one can directly observe the reduction in the amide I and amide II bands due to the degradation of the albumen binder (Fig. 24).

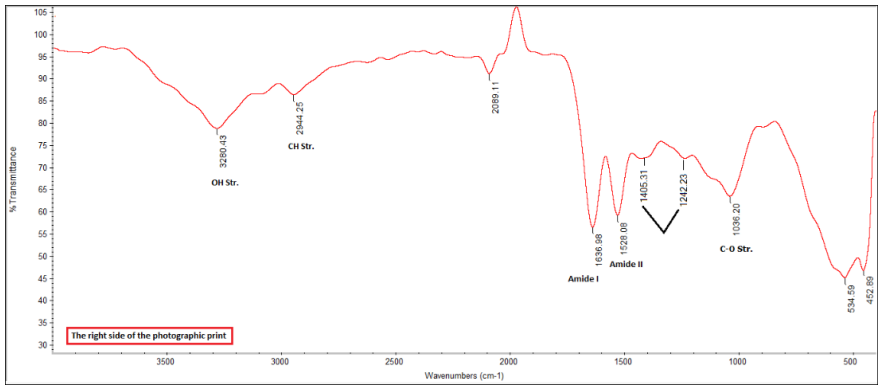

Fig. 23. FTIR spectrum of the right side of the photograph showing minor deterioration

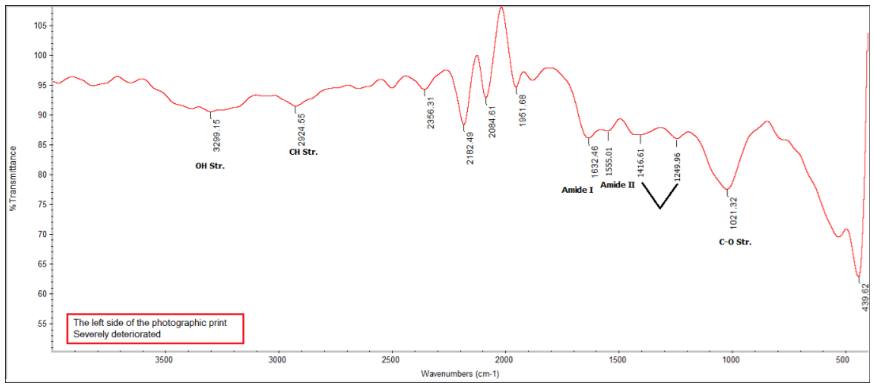

Fig. 24. FTIR spectrum of the left side of the photograph showing severe deterioration

As for the secondary support, it reveals the presence of functional groups characteristic of cellulose, with absorption bands at 3382.47cm^{-1} corresponding to OH stretching vibrations; 2904.56cm^{-1} corresponding to CH_2 symmetrical stretching; 1635.71cm^{-1} corresponding to vibration of water molecules absorbed in cellulose; 1432.22cm^{-1} corresponding to CH_2 deformation stretching; 1327.66cm^{-1} corresponding to CH deformation stretching; 1245.7 - 1432.22cm^{-1} corresponding to OH and CH bending vibrations; and 1066.57 – 900.90cm^{-1} corresponding to C-O stretching of COH/C-O-C [30]. The strong increase in the intensity of the absorption band at 1644.19cm^{-1} is associated with the oxidation of cellulose, which results in the creation of carbonyl (C=O) groups; these chromophores are responsible for the yellowing of paper as it ages [30, 70]. Furthermore, oxidation induces depolymerization of the cellulose; as a result, the mechanical strength of the material decreases (Fig. 25) [68].

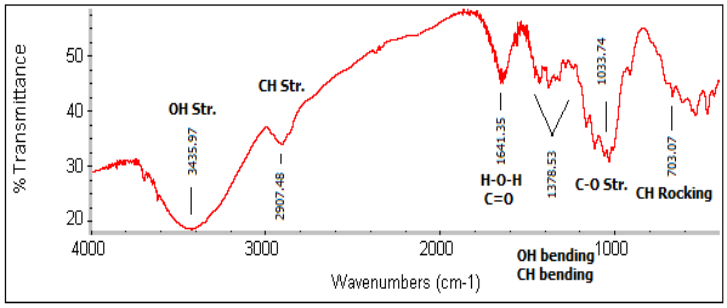

Fig. 25. FTIR spectrum of the secondary support showing 1st degree oxidation

Microbiological studies

Superficial fungal colonies were clearly visible and abundant on both the albumen print and the secondary support. Despite the significant signs of biodeterioration, only weak fungal populations were isolated (20 CFU·m^{-2}), which is considered less than that isolated from stored photographs and maps from the 19th and 20th centuries (i.e., 10^1 to 10^3CFU·cm^{-2}) as reported by *S. Borrego et al.* [71]. Fungi documented on the examined photograph belonged to two genera, *Aspergillus* and *Emercilla*, while that inhabiting the aerosol belonged to four genera: *Aspergillus*, *Cladosporium*, *Emercilla,* and *Penicillum,* as shown in Table 3 and Figure 26. *A. niger* and *Emercilla nidulans* were isolated from the examined photograph; however, only *A. niger* seemed to be the causative agent of biodeterioration, as clearly apparent from the visual inspection, while *E. nidulans* was represented by only one colony, perhaps from the air. Five fungal species were detected on the photograph surface; *A. niger* was the dominant fungal isolate in the air of the examined room [50]. According *to S. Borego et al.* [72], the main cause of the biodeterioration of the photograph collections in the photographic library of the national archive of the republic of Cuba and in the historical archive of the museum La Plata was the yeasts and filamentous fungi of the *Aspergillus* and *Penicillium* genera.

Table 3. Fungi isolated from deteriorated photograph surface and air before and after mechanical treatment

Treatment	PDA		CA		Mycobiota	
	Fungal species	Fungal load (CFU.m^{-2})	Fungal species	Fungal load (CFU.m^{-2})	Fungal species	Fungal load (CFU.m^{-3})
Before	*Aspergillus niger*	20	*A. niger* *Emercilla nidulans*	4	*Aspergillus flavus* *E. nidulans* *Cladosporium* sp. *Penicillium* sp.	131
After	No growth	-	No growth	-	No growth	-

* There is no growth observed on MEA and NA media

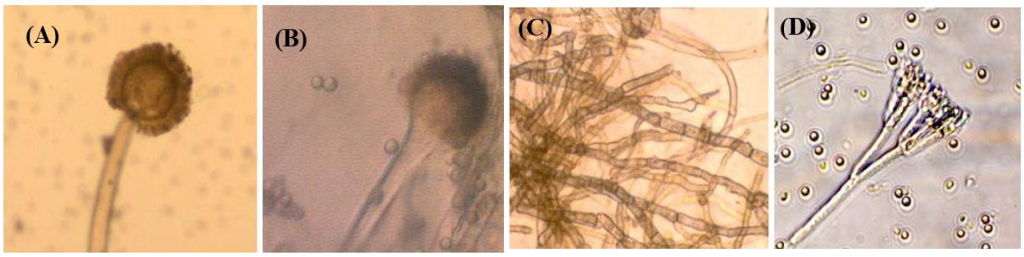

Fig. 26. Fungi isolated from a deteriorated photograph and air:
A. *Aspergillus niger* **B**. *Aspergillus flavus*, **C**. *Cladosporium* sp., **D**. *Penicillium* sp.

It is well known that mold produces organic acids [73], which promote acid hydrolysis of the attacked materials [74]. It was noticed that the pH of the bio-deteriorated part of the photograph decreased to 4.9 due to the *A. niger* infection. *H. Saada et al.* [75] confirmed the biodeterioration ability of *A. niger* represented by its cellulase activity and the ability to acidify the medium. They added that a decline in pH to 5.2 was confirmed in the *A. niger*-infected papyrus sample. The authors concluded that the biodeterioration ability of the isolated mold greatly contributed to the cracks and the damage that appeared clearly in the albumen print.

After mechanical treatment and transferring the object to the controlled environment, the isolation was repeated, and no growth was observed from either the photograph or the air, which confirmed the crucial role of the environment in the controlling of biodeterioration. The results obtained by *M. Osman et al.* [76] explained how the storage temperature is the main factor impacting the microbial attack of stored photographs. They added that the lower the temperature at which the photographs were stored, the lower the microbial attack risk.

Conclusions

Muhammad Sadiq Bey (1832–1902), an Egyptian army engineer and surveyor who served as treasurer of the Hajj pilgrim caravan, is a distinguished Egyptian photographer known for his remarkable images of the holy sites of Islam at Mecca, Madina, Arafat, and Mena and the Hajj, taking the first-ever photographs in what is now Saudi Arabia. His photographic achievements were recognized by both the Arab and European worlds, and in 1881, he won a gold medal at the Venice Geographical Exhibition.

A part of Sadiq Bey's collection is housed at the Egyptian Geographic Society, which was established by a decree of Khedive Ismail Pasha in 1875. This complex is located at the heart of Cairo and comprises an ethnographic museum, a debating chamber, and a historical library. The society's museum holds thousands of artifacts, documents, maps, photographs, and other items, mostly from the 18th to early 20th century, that provide insights into the geography, geology, climate, and culture of Egypt and Africa.

Sadiq Bey used the albumen process to produce his positive images. Albumen prints were produced by contact printing a wet collodion glass negative on a sheet of sensitized albumen photographic paper. Basically, an albumen print is composed of a primary paper support (i.e., rag paper), an albumen binder layer (i.e., egg white), and silver particles as the final image material. The image exhibits a shift of color toward darker-brown or violet-black tonalities.

Albumen prints are susceptible to damage by many agents such as natural aging, poor processing, inappropriate temperature and relative humidity levels, inappropriate light levels, biological threats, pollutants, inappropriate storage and display, mishandling and misuse, disasters, and inappropriate conservation treatments.

This paper studies a framed 19th -century albumen print of Mount Arafat captured by Sadiq Bey in 1880. The hill and day of Arafat hold great significance in Islam; it is an essential part of Hajj. The following examination and analytical techniques were used to document and evaluate the condition of the photograph and develop a proper conservation plan: visual inspection, stereomicroscope, UV and IR imaging, scanning electron microscopy coupled with energy dispersive x-ray fluorescence spectrometry (SEM-EDS), pH value measurement, Fourier transform infrared spectroscopy (FTIR), and microbiological examination.

Visual and microscopic inspection revealed that the binder layer suffers from overall yellowing and a network of fine cracks, characteristic of albumen print deterioration. It also exhibits microbiological deterioration in the form of black stains, flaking binder, and losses. The image layer mainly shows fading and discoloration. The primary support is brittle and separated from the secondary support. The secondary support suffers from yellowing, embrittlement, and acidity. It also shows black mold stains.

UV imaging was unuseful, while IR imaging revealed the presence of a retouching medium. SEM examination showed the existence of a network of micro-cracks on the surface of the photograph and fungal spores. EDS analysis showed the presence of silver as the final image material. The presence of gold (Au) and chloride (Cl) indicated that the image was gold-toned. The compound responsible for image decay is silver sulfide, as indicated by the presence of sulfur. The absence of barium (Ba) in the baryta layer confirms that the photographic process used to produce the image is the albumen process.

The average pH value for the secondary support was 4.9, indicating that it suffers from acidity.

FTIR analysis of the binder layer reveals the presence of amide I and amide II bands characteristic of proteins (i.e., albumen and gelatin). In albumen prints, the two peaks in the spectral region between 1470 and 1250cm^{-1} are of the same intensity, which is the case in this study. By comparing the left side of the image with the right side, results show that the left suffers severe degradation as indicated by the reduction in the amide I and amide II bands. As for the secondary support, the FTIR results reveal the presence of the functional groups characteristic of cellulose. It also shows a strong increase in the intensity of the absorption band at 1644.19 cm^{-1}, which is associated with the oxidation of cellulose resulting in the formation of carbonyl (C=O) groups; these are responsible for the yellowing of paper as it ages. Oxidation induces depolymerization of the cellulose; as a result, the mechanical strength of the material decreases.

Both *Aspergillus niger* and *Emericella nidulans* were isolated from the examined albumen print; nevertheless, only *A. niger* seemed to be the causative agent of biodeterioration, as apparent from visual inspection of the surface of the photograph. The decrease in pH value of the secondary support to 4.9 is partially due to the ability of *A. niger* to produce organic acids, which promote acid hydrolysis of attacked materials. The authors concluded that the biodeterioration ability of the isolated mold greatly contributed to the cracks and the damage that appeared clearly in the albumen print.

Based on the obtained results, a conservation plan was developed to be carried out as soon as possible to enhance the photograph's appearance and physically and chemically stabilize its condition to protect it from future damage. Given the fact that albumen prints are very sensitive, the authors decided to limit the treatments to only those which are necessary. Treatments were carefully chosen on the basis that they respect the aesthetic, historic, and physical integrity of the photograph. The selected treatments include removing the photograph from the frame, disinfection, mechanical cleaning, minor solvent cleaning, deacidification, consolidation, compensating for losses, minor retouching, and housing.

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References

[1] M. Reed, **The Role of Photography in Society: A Look at the Power of Visual Storytelling**, Edvigo Academy, 2024. https://edvigo.com/humanities/role-photography-society-look-power-visual-storytelling/#:~:text=Photography%20allows%20us%20to%20freeze%20a%20moment%20in%20experience%20historical%20moments%20that%20would%20otherwise%20be%20lost

[2] A. Stock, **Mecca's**, Art & Books, 2022. https://www.abouther.com/node/14306/entertainment/art-books/mecca%E2%80%99s-first-photographers-%E2%80%9Cno-one-me-has-ever-taken-such.

[3] Q. Khan, **"Photographic Views of Hajj, by Muhammad Sadiq Bey" in Explore Islamic Art Collections**, Museum with no Frontiers, 2024, https://islamicart.museumwnf.org/database_item.php?id=object;EPM;uk;Mus22;2;en.
[4] M. Ritter, S. Scheiwiller, *Introduction: Early Photography in the Near and Middle East and the Notion of an "Indigenous Lens,"* **The Indigenous Lens? Early Photography in the Near and Middle East** (Eds: M. Ritter, S.G. Scheiwiller), (Studies in Theory and History of Photography; 8), De Gruyter, 2018. DOI: 10.1515/9783110590876-003.
[5] B. Baldwin, M. Jürgens, **Looking at Photographs: A Guide to Technical Terms**, Revised edition, Getty Publications, Los Angeles, 2009.
[6] D. Stulik, A. Kaplan, **The Atlas of Analytical Signatures of Photographic Processes: Albumen**, J. Paul Getty Trust, Los Angeles, 2013.
[7] The J. Paul Getty Museum, **Louis Désiré Blanquart-Evrard, The Museum's Collection Database**, J. Paul Getty Trust, 2013. https://www.getty.edu/art/%20col%20lection/artists/1992/louis-dsir-blanquartevrard-french-1802-1872/ [accessed 6/12/2020].
[8] J. Reilly, **The Albumen & Salted Paper Book: The History and Practice of Photographic Printing (1840-1895)**, Light Impressions, NY, 1980.
[9] W. Leyshon, **Photographs from the 19th Century: A Process Identification Guide**, Prescott, AZ: Sharlot Hall Museum Archives, USA, 2012.
[10] A. Puškárová, M. Bučková, B. Habalová, L. Kraková, A. Maková, D. Pangallo, *Microbial communities affecting albumen photography heritage: A methodological survey*, **Scientific Reports**, **6**, Article Number: 20810, 2016, pp. 1-14. https://doi.org/10.1038/srep20810.
[11] E. Young, **Mechanism of Controlling Colour and Aesthetic Appearance of the Photographic Salt Print**, MA, School of Applied Sciences, RMIT University, Australia, 2008.
[12] J. Sturge, **Neblette's Handbook of Photography and Reprography: Materials, Processes, and Systems**, 7th edition, Van Nostrand Reinhold, NY, 1977.
[13] * * *, **Image Permanence Institute**, **The Graphic Atlas: albumen, Image Permanence Institute**, College of Art and Design, Rochester Institute of Technology (RIT), 2024. http://www.graphicsatlas.org/identification/?process_id=143#overview.
[14] A. Brost, L. Casella, S. Watkins, **Albumen**, Wiki: A Collaborative Knowledge Resource, the Photographic Materials Group, the American Institute for Conservation (AIC), 2012. https://www.conservation-wiki.com/wiki/Albumen.
[15] * * *, **National Park Service, NPS Museum Handbook: Part I, Museum Collections**, 1996. https://www.nps.gov/museum/publications/MHI/Appendix%20R.pdf.
[16] P. Messier, *Protein Chemistry of Albumen Photographs*, **Topics in Photographic Preservation**, **4**, 1991, pp. 124-135. (Photographic Materials Group of the American Institute for Conservation of Historic & Artistic Works).
[17] J. Reilly, *Albumen prints: A summary of new research about their preservation*, **Picturescope**, **30**(1), 1982, pp. 34-37.
[18] J. Reilly, D. Severson, C. McCabe, *Image deterioration in albumen prints*, **Science & Technology in the Service of Conservation. IIC Congress**, Washington DC, September 1982, pp. 61-64.
[19] S. Clark, **Preservation of Photographic Materials**, The Preservation Advisory Centre, the British Library, 2009. https://www.bl.uk/aboutus/stratpolprog/collectioncare/publications/booklets/preservation_of_photographic_material.pdf [accessed 11/5/2017].
[20] J. Donaldson, **Preservation Notes: Caring for Photographs and Paper Workshop**, New South Wales, 2000. http://www.magsq.com.au/_dbase_upl/training_pres_photospaper.pdf.
[21] G. Weaver, **A Guide to Fiber-Based Gelatin Silver Print Condition and Deterioration**, Adobe Calson, Pro, Catriel, and Tandelle, 2008.

[22] E. Małachowska, M. Dubowik, P. Boruszewski, J. Łojewska, P. Przybysz, *Influence of lignin content in cellulose pulp on paper durability*, **Scientific Reports**, **10**(1), 2020 Article Number: 19998. https://doi.org/10.1038/s41598-020-77101-2.

[23] K.L. Kato, R.E. Cameron, *A review of the relationship between thermally-accelerated ageing of paper and hornification*, **Cellulose**, **6**(1), 1999, pp. 23-40. DOI: 10.1023/A:1009292120151.

[24] C. Vischi, G. Hill, *The study of two humidification and flattening methods for albumen prints to determine their impact on the evolution of cracks in the albumen layer*, **Restaurator-International Journal for the Preservation of Library and Archival Material**, **29**(2), 2008, pp. 45-75. DOI: 10.1515/rest.2008.004.

[25] M. Seery, **Paper Conservation**, Royal Society of Chemistry, 2013. https://edu.rsc.org/feature/paper-conservation/2020204.article.

[26] J. Kosel, P. Ropret, *Overview of fungal isolates on heritage collections of photographic materials and their biological potency*, **Journal of Cultural Heritage**, **48**, 2021, pp. 277-291. DOI: 10.1016/j.culher.2021.01.004.

[27] E. Adcock, M. Varlamoff, V. Kremp, *IFLA principles for the Care and Handling of Library Materials*, **International Preservation Issues**, **1**, International Federation of Library Associations and Institutions Core Programme on Preservation and Conservation and Council onLibrary and Information Resources, 1998. http://www.ifla.org/files/assets/pac/ipi/pchlm.pdf.

[28] H. Eldeeb, M. Ali, M. Mansour, M. Ali, *Investigation and conservation of a private photographic collection of albumen prints, Egypt*, **Egyptian Journal of Archaeological and Restoration Studies**, **12**(1), 2022, pp. 41-52. DOI: 10.21608/ejars.2022.246575.

[29] L. Egunnike, **Preservation of Works on Paper**, Arts Torque, 2003.

[30] M. Ali, M. Ali, S. Darwish, U. Saker, E. Ciliberto, E. Greco, E. Viscuzo, *Investigation and Conservation of El-Shenawy Palace photographic Collection in Mansoura, Egypt*, **Mediterranean Archaeology and Archaeometry**, **15**(3), 2015, pp. 165-185. DOI:10.5281/zenodo.27744.

[31] B. Lavédrine, **A Guide to The Preventive Conservation of Photograph Collections,** Getty Publications, USA, 2003.

[32] M. Roosa, **Caring, Handling and Storage of Photographs**, Information Leaflet, The Library of Congress. 2006. http://www.loc.org/preserv/care/photolea.html#Storage.

[33] H. Wilhelm, B. Carol, **The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures**, Preservation Publishing Company, U.S.A., 1993.

[34] O. Abdel-Aziz, M. Mahmoud, Y. Abo-Elfath, S. Abdel-Aziz, M. Samir, M. Ali, *Evaluation of conventional treatments for mirrored silver gelatin prints: Experimental and applied study*, **International Journal of Conservation Science**, **10**(1), 2019, pp. 81-96.

[35] F. Durant, **Albumen Prints: their history, conservation, and care**, 2005. http://www.ischool.utexas.edu/~fdurant/Project_pages/Albumen%20Final.doc

[36] S. Clark, F. Frey, **Care of Photographs**, European Commission on Preservation and Access, 2003. http://www.knaw.nl/ecpa/sepia/linksandliterature/CareOfPhotographs.pdf.

[37] M. Ali, M. Ali, S. Darwish, U. Saker, E. Ciliberto, *Solvent cleaning of antique chromogenic prints: an analytical comparative study*, **Mediterranean Archaeology and Archaeometry**, **17**(3), 2017, pp. 1-12. DOI: 10.5281/zenodo.1005426

[38] J.L. Bigourdan, P.Z. Adelstein, J.M. Reilly, **Moisture and Temperature Equilibration Behavior and Practical Significance in Photographic Film Preservation**, 1997. https://api.semanticscholar.org/CorpusID:58899129.

[39] M. Ali, M. Fawzy, *The effect of the vapors of clove and lavender oils on the chemical and optical properties of silver gelatin prints in wood frames*, **International Journal of Conservation Science**, **12**(3), 2021, pp. 961-976.

[40] F. Mahmood, **Mount Arafah – Jabal ar-Rahmah – Facts and Significance in Islam**, Pilgrim Knowledge, 2024. https://thepilgrim.co/mount-arafat/.
[41] R. Butt, **The Hajj is Not Mecca: Why Prayers at Mount Arafat are the Spiritual Peak of Islamic Pilgrimage**, 2023. https://apnews.com/article/hajj-arafat-saudi-arabia-islam-religion-38106bdbf376084a8d5f71e4c2fa7379.
[42] * * *, **Mina, Arafat, and Muzdalifah**, Hajj Council of North America, 2023. https://hajjcouncil.org/mina-arafat-and-muzdalifah/.
[43] C. Chaisrisook, P. Suwannarit, C. Aranyanak, *Fungal deterioration of mural paintings in the royal temple*, **Proceedings of the 3rd International Conference on Biodeterioration of Cultural Property**, Bangkok, Thailand, 1995, pp. 116-137.
[44] J.W. Deacon, **Introduction to Modern Mycology, Blackwell Scientific Publications**, Wiley, 1997, p. 303.
[45] J.L. Pitt, **The genus Pencillium and its Teleomorph States Eupencillium and Talaromyces**, Academic Press, New York, 1979, pp. 50-55.
[46] K.B. Raper, D.I. Funnel, **The Genus Aspergillus**, Robert E. Krieger Publication Co., New York, 1977, 686p.
[47] K.H. Domsch, W. Gams, T.H. Anderson, **Compendium of Soil Fungi**, Academic Press, London, 2nd edition, 2007, 672p.
[48] S. Guild, M. MacDonald, **Mould Prevention and Collection Recovery: Guidelines for Heritage Collections**, CCI Technical Bulletin, 2007.
[49] V.L. Omelyansky, **Manual in Microbiology,** USSR Academy of Sciences, Moscow, Leningrad, 1940.
[50] M. Ljaljević Grbić, M. Stupar, J. Vukojević, I. Maricic, N. Bungur, *Molds in museum environments: Biodeterioration of art photographs and wooden sculptures*, **Archives of Biological Sciences**, **65**(3), 2013, pp. 955-962. DOI: 10.2298/ABS1303955G.
[51] S. Borrego, P. Guiamet, I. Vivara, P. Battistoni, *Fungi involved in biodeterioration of documents in paper and effect on substrate*, **Acta Microscopica**, **27**(1), 2018, pp. 37-44.
[52] P. Read, M. Meyer, **Restoration of Motion Picture Film**, Butterworth-Heinemann, Great Britain, 2000.
[53] M. Ali., *Effect of five essential oils as green disinfectants on selected photographic prints: Experimental study*, **Conservation Science in Cultural Heritage**, **20**(1), 2020, pp. 79-97. https://doi.org/10.6092/issn.1973-9494/12791.
[54] * * *, **Conservation of Photographs**, Eastman Kodak Company, 1985.
[55] P.L. Benson*, Some unusual, hidden, surprising, or forgotten sources of (possible) sulfur contamination in museums and historic structures*, **Objects Specialty Group Postprints**, **19**, 2012, pp. 85-107, The American Institute for Conservation of Historic & Artistic Works.
[56] E. Małachowska, D. Pawcenis, J. Dańczak, J. Paczkowska, K. Przybysz, *Paper Ageing: The Effect of Paper Chemical Composition on Hydrolysis and Oxidation*, **Polymers**, **13**(7), Article Number: 1029, 2021. DOI:10.3390/polym13071029.
[57] Library of Congress, **The deterioration and preservation of paper: some essential facts**, 2024. https://www.loc.gov/preservation/care/deterioratebrochure.html.
[58] T. Łojewski, K. Zięba, A. Knapik, J. Bagniuk, A. Lubańska, J. Łojewska, *Evaluating paper degradation progress, Cross-linking between chromatographic, spectroscopic and chemical results*, **Applied Physics A**, **100**(3), 2010, pp. 809-821. DOI: 10.1007/s00339-010-5657-5.
[59] * * *, **Basic Conservation of Archival Materials**, Revised edition, Chapter 6: Collections, Canadian Council of Archives, 2003. https://archivescanada.ca/wp-content/uploads/2022/08/RBch6_en.pdf.
[60] * * *, **Spencer Entomological Collection**, The Spencer Entomological Museum, 2024. https://www.zoology.ubc.ca/entomology/main/Coleoptera/Dermestidae/Anthrenus%20lepidus%20larval%20case%20(1dorsal).jpg.

[61] L. Simon, F. Boukari, H. Oumarou, T. Hubiche, P. Marty, C. Pomares, P. Delaunay, *Anthrenus sp. and an uncommon cluster of dermatitis*, **Emerging Infectious Diseases**, **27**(7), pp. 1940-1943. https://doi.org/10.3201/eid2707.203245.

[62] G.J. Holloway, D.B. Pinniger, *Anthrenus species (Coleoptera; Dermestidae) found in UK museums with special reference to A. museorum Linnaeus, 1761, the museum beetle*, **Journal of Natural Science Collections**, **7**, 2020, pp. 69-71.

[63] A. Cosentino, *Infrared Technical Photography for Art Examination*, **Cultural Heritage Science Open Source – CHSOS**, Morana RTD d.o.o., 2016.

[64] P. Messier, T. Vitale, *Effects of aqueous treatments on albumen photographs*, **Journal of the American Institute for Conservation**, **33**(3), 1994, pp. 257-278.

[65] M. Ali, *The evaluation of agarose-based gel systems for surface cleaning albumen prints vs the conventional water treatment*, **Egyptian Journal of Archaeological and Restoration Studies**, **12**(1), 2022, pp. 7-27. DOI: 10.21608/ejars.2022.246573

[66] Y. Adigüzel, P. Haris, F. Severcan, *Screening of proteins in cells and tissues by vibrational spectroscopy*, **Advances in Biomedical Spectroscopy**, **6**, IOS Press BV, Netherlands, 2012, pp. 53-108. DOI: 10.3233/978-1-61499-059-8-53.

[67] A. Mahmoud, O. Osman, K. Eid, E. Al Ashkar, A. Okasha, D. Atta, M. Eid, Z. Abdel Aziz, A. Fakhry, *FTIR spectroscopy of natural bio-polymers blends*, **Middle East Journal of Applied Sciences**, **4**(4), 2014, pp. 816-824.

[68] M. Fawzy, *A Comparative study on the effect of cleaning materials on the chemical composition and mechanical properties of damaged and undamaged wood with the application of chosen archaeological wood*, **PhD Thesis**, Conservation Department, Faculty of Archaeology, Cairo Univ., Egypt, 2016.

[69] C. Ricci, S. Bloxham, S.G. Kazarian, *ATR-FTIR imaging of albumen photographic prints*, **Journal of Cultural Heritage**, **8**(4), 2007, pp. 387-395. DOI: 10.1016/j.culher.2007.07.002.

[70] V. Hospodarova, E. Singovszka, N. Stevulova, *Characterization of cellulosic fibers by FTIR spectroscopy for their further implementation to building materials*, **American Journal of Analytical Chemistry**, **9**, 2018, pp. 303-310. https://doi.org/10.4236/ajac.2018.96023.

[71] S. Borrego, A. Molina, A. Santana, *Mold on stored photographs and maps: A case study*, **Topics in Photographic Preservation**, **16**, 2015, pp. 109-120. (Photographic Materials Group of the American Institute for Conservation of Historic & Artistic Works).

[72] S. Borrego, P. Guiamet, S. Gómez de Saravia, P. Batistini, M. Garcia, P. Lavin, I. Perdomo, *The quality of air at archives and the biodeterioration of photographs*, **International Biodeterioration & Biodegradation**, **64**(2), 2010, pp. 139-145. DOI: 10.1016/j.ibiod.2009.12.005.

[73] S. Borrego, O. Valdés, I. Vivar, P. Lavin, P. Guiamet, P. Battistoni, S. Gómez de Saravia, P. Borges, *Essential oils of plants as biocides against microorganisms isolated from Cuban and argentine documentary heritage*, **ISRN Microbiology**, **2012**, 2012, Article Number: 826786. https://doi.org/10.5402/2012/826786.

[74] F. Pinzari, *Microbial ecology of indoor environments: the ecological and applied aspects of microbial contamination in archives, libraries and conservation environment,* **Sick Building Syndrome** (Editor: S.A. Abdul-Wahab), Springer, 2011, pp. 153-178.

[75] H. Saada, M. Othman, M. Khaleil, *Mold-deteriorated archaeological Egyptian papyri: biodeteriogens, monitoring the deterioration, and treatment approach*, **Archaeometry**, **65**(2), 2022, pp. 335-353. https://doi.org/10.1111/arcm.12831.

[76] M. Osman, S. Ismael, E. Ciliberto, S. Stefani, Y. Elsaba, *Evaluation of microbial deterioration of silver gelatin photographs stored in an old photographic archive*, **International Journal of Conservation Science**, **13**(2), 2022, pp. 527-540.

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