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INPUT OF THE TECHNICAL IMAGING FOR THE STUDY OF WALL PAINTINGS: EXAMPLE OF A LINTEL (TOMB OF KING TAKELOT I AT TANIS-SAN EL-HAGAR, SHARQEYA, EGYPT)

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Abstract:
Technical digital imaging is a non-destructive and contactless technique that is increasingly used to study wall paintings. The methodology is based on the images acquisition in different wavelengths domains. A painted lintel in the tomb of King Takelot I (22nd dynasty, 887-873 BC), at the archaeological site of Tanis (Egypt), which shows a fragile surface, has been investigated in this way. Images under direct light, raking light, favouring near IR radiation, catching the fluorescence response under UV have been made. Ortho-photographs and generated depth maps at both macro- and micro-scales using a digital camera and contactless e-microscope have also been performed. The images revealed the presence of Egyptian blue, red ochre, carbon black. They also have provided additional information on the degradation patterns and the nature of soluble salts that are chloride and sulphate-based compounds, the main origin of the degradations and helped to detect the traces of past restoration.

1. Introduction

Archaeological sites often suffer severe changes of their environment after their discovery and excavation. This can lead to the interlock of degradation processes. Conservation issues are then of a great concern to ensure its permanence more especially in presence of wall paintings and polychrome. This is the case at the Egyptian archaeological site of Tanis, and particularly its painted royal tombs, a funerary complex of fifteen burials of some kings and princes of the 21st and 22nd dynasties (1039-769 BC). The vast site of the ancient city of Tanis is situated in the low plain of the North-eastern Nile Delta, some 120 km$_s$ of Cairo. Tanis was founded at the very end of the 2nd millennium BC and its occupation did not stop before the end of late antiquity, some 1800 years later. During the first part of its history — the Third Intermediate Period (1069-664 BC) — the locality was the capital of Egypt. Some of the kings and princes of this period had their burial built inside the enclosure of the main temple of the city. King Takelot I (887-873 BC), one of the rulers of the 22nd dynasty, was buried in one of the chambers, built in limestone, of the large tomb of his son Osorkon II. The royal necropolis of Tanis was discovered by French archaeologist Pierre Montet in spring 1939, a few months before World War II. Part of it had been plundered, but several burials were found intact. Montet [1-3] continued the excavations and study of the tombs in spring 1940 and in the years immediately after the war (1945-1946). The complex is at quite a low altitude, in a depression of the natural sandy subsoil within the south-west corner of the sacred area. With the geological phenomena of subsidence of the Delta region and the rise of the level of ground water, the ground water table rose and is now just below the foundations of the tombs. The site has always been subject to frequent and heavy rainwater floods [4] during winter and sometimes also in spring. The tomb structures (mainly made of limestone, granite, and quartzite) as well as the surrounding subsoil are saturated with salts — the site is not far from the sea and sea-shore lagoons, which were actually much closer during the antiquity. Today, the regular alternation of episodes of moistness brought by the rains, the ground water and the morning dew, and dryness leads to the constant migration and crystallization of the salts, particularly towards the walls of the tombs, causing some important damages on the decoration. This was already noted by the archaeologists when they entered the tombs and increases since their discovery. Much later, archaeologists proceeded to some interventions aiming to limit the water inflows from 1987, while local authorities applied a protective resin on some painted surfaces from 1978 [5]. This latter treatment quickly turned out to be harmful to the painted surfaces. In another way, regular restoration campaigns including desalting and cleaning of these surfaces have been regularly performed [6]. In 2015, Fr. Leclère, head of the French excavation mission at Tanis has been concerned about severe floods affecting the site, particularly the tombs, and requested an expertise mission to assess the consequences on their conservation [4,7-9]. This preliminary study led to the implementation of an in-depth study of the painted surface of the tombs and their conservation issues to precisely define the best restoration protocol to implement in the future. Several specialists were invited to come to the site in order to make some observations and analyses and to give some conservation diagnosis elements on the stone degradation (P. Bromblet, CICRP), the microbiological colonization (F. Bousta, LRMH), the climatic behaviour of the tombs (S. Moularat, CSTB), and a fist evaluation of the restoration needs (S. Duberson and J. Le Roux, musée du Louvre; N. Timbart, C2RMF; A. Liégey independent conservator). A study of the hydrogeology of the site focusing on the area of the tombs has also been performed (S. Pistre and T. Navarro, university of Montpellier) from 2018 to 2020 [10-14]. As part of this project, an in-depth study of the wall paintings of the internal spaces of the royal tombs as well as their conservation issues, using scientific imaging, was also carried out by É. Hubert-Joly, J.-M. Vallet, CICRP; [12,15]. This is this aspect of the research that will be developed in the present article. The study of wall paintings and polychromies that are often fragile first needs the implementation of contactless and non-destructive techniques. At first, the methods of analyses that can give information on pictorial techniques and materials conservation state are favored. Technical imaging or scientific images [16] is one of these techniques that for long appear as essential tools for conservation sciences [17]. It has been developed during the first half the twentieth century for the study of paintings on canvas and rapidly became of common use [18,19]. This technique is now widely used to study other cultural heritage such as wall paintings and polychromies and became recently of more interest and easier to use thanks to digital cameras [20]. Technical imaging has been implemented in 2020 to complete the documentation of

Tanis' tombs wall paintings and to document their current conservation state in the framework of the current conservation study of the site [12]. The aim of the study in high-resolution digital technical imagery was to obtain a precise cartographic condition report of a few painted surfaces that have been selected as representative of the state of conservation of the whole paintings in February 2020. It is the first step of a diagnosis process involving NDT tools.

2. Review on the input of the technical imaging to the study of wall paintings

Technical imaging is a part of the photographic documentation that can give information on materials [16] as it is a multiband methodology [21]. First, images are collected under direct light. In addition, different other shooting techniques are currently used. Each of them provides additional information by comparing them to each other. Information can be drawn from their combination, and provide elements that help to identify some materials, understand degradation processes, and determine their active character. First, images were acquired under a visible and artificial light (VIS). Their usefulness depends on their quality and the use of a color chart and a scale. They aim to reproduce as faithfully as possible the observed artwork and are enabled to restitute fine details thanks to the high resolution of digital sensors. The conservation state of the pictorial layers and the painting technique are thus investigated. These images help to locate the over-paints too [19]. In another way, digital microscopes are now used to make accurate observations of the surfaces and give important additions to digital photo-documentation. As the surface elief testifies of murals conservation state, images under a raking light are also performed. In a general point of view, a raking light is defined as a light beam that stands an angle from few degrees to 30° to the investigated surface [16]. It allows highlighting the roughness of the surface layers through shadow effects. A surface lighting with around 20° as the angle is generally favored to make enable the readability of the artwork and its relief (semi raking light, marked as RAK hereinafter) too. First RAK in the field of cultural heritage were made in the 1930's, in particular in France by F. Perez [22]. Deformations and surface accidents can be then clearly showed and help to understand better the alteration phenomena. Cupping, flaking, delamination, cracks, and loss of material can then be clearly revealed [16,19,23] as well as the execution of the painting and the retouches. It is a qualitative assessment that needs different points of view using overhead lights, lights from below, left, or right. Technical imaging also explores some physicochemical properties of paintings materials that are revealed using non-visible radiation. In this way, imaging of the materials response to infrared light (wavelength domain: 0.78 to 1 mm) and more particularly in the near infrared domain, is of common use [24]. Near infrared wavelengths are comprised from 0.78 to 30 µm and a part of them (0.78 µm to 10 µm) is used in digital IR photographs for the studies of paintings and polychromies. The first IR photograph was published in October 1910, but IR photography on artworks became possible and was carried out in France by Perez and Mainini in the 1930's [22]. This technique expanded from the 60's (see. R. J. van Asperen de Boer, cited by [25] and developed in different IR photography techniques that are IR imaging which captures reflected radiation (IRd), transmitted IR where IR sources are behind the artwork (generally unsuitable for wall painting), false color (IRfc) and IR fluorescence (IRf) in the IR domain [25]. IRd makes thus it possible to clarify a scene by crossing, to different degrees, the responses of different pigments; some are transparent, others opaque to near infrared radiation. Note that pigments become "transparent" to IR at a middle IR wavelength (6-15 µm; [25,26]. This helps revealing faded pigments such as carbon which is an IR absorbing material [25] and can help in reading and interpreting the compositions, revealing the presence of these materials in the painting subsurface layers. It also can reveal traces of non-visible materials (i.e., pigments), the underdrawing or detects some alterations, overpaintings, and retouchings [24]. The combination of the IR image, which is in black and white, with the VIS one, allows generating an IRfc image. IRfc facilitates images reading because the gray levels of the IR image are translated into a range of colors. It makes it also possible to differentiate some pigments of the same color in visible light, thanks to the differences of the materials in absorption of IR radiation. As an example and in presence of pure material or simple mixture, pigment recognition is possible by comparing the IRfc image of pigments with the IRFc response of references using the same shooting protocol. IRfc can then give accurate information on the nature of the material. It can allow detecting retouching [25,27,28]. Odin and Carter presented the input of this technique in 1968 [29] they gave a set of photographs showing the colors evolutions of tube colors and pigment manufacturers between a standard observation under a visible light and using this technique. Matteini, et al. [30] also performed research on this IR application and obtained results that differed from [29] ones, mainly because of the use of different Kodak film types. The digital revolution made easier to use this observation technique. Some authors [31-33] proposed thus such references. Weak differences can exist between them depending on the nature of the observed material (single pigment, mixture, addition, and nature of the binder). The analyst has therefore to carefully use his/her own references or the proposed references coming from literature. These references should go with an accurate and available shooting protocol. Some materials also photo-induces luminescence in the IR domain (IRl; Barnes, 1958 cited by Cosentino [25]. This luminescence, not visible, is transcribed by the camera's modified sensor. This is the case for Egyptian blue, Han blue and purple, Cadmium red, yellow, and green [25,34]. More particularly, Egyptian blue can be detected even as traces [35]. In another way, photography under Ultraviolet radiation (UV) allows visualizing the nature of some surficial constituents on the surface layer. Its first uses with regard to painted cultural heritage were carried out in the 1930's in France [36-38]. It is more particularly useful to know the original decoration and to consider their aspect before the ageing [39]. During the first decades of using this technique, Wood's lamps were employed. However, the degradations induced by these lamps led to their replacement by UV fluorescence tubes, less dangerous for the works and notably for the organic materials constituting them. Now LED technology is going to be preferred. The chosen light, which is violet, emits a strong radiation at 365 nm. It causes the fluorescence of certain chemical compounds (UVf), organic as well as inorganic on the surface of materials. This examination notably makes it possible to distinguish superficial restorations and to locate certain resins used in old restorations and present on paintings, as well as alterations (i.e., crusts, efflorescence of certain soluble salts). More, the tints of inorganic materials, which fluoresces under UV radiation in the visible range, can help in the determination of their nature and their accurately location. Reflected UV photography (UVr) is less employed than UVf because the results are more hardly readable [40]. UVr can help to find retouches and gives complementary information on varnishes. It is mainly used on manuscripts to reveal faded iron gall inks.

Reflected UV in False Color (UVfc) is however a more interesting technique and quite new technique that was developed in 2004. It can be combined with IRfc and help to the characterization of materials that are present on the painted surfaces [31]. More particularly, these authors show that UVfc can discriminate some white pigments and helps to better analyze surface coatings. More recently, orthophotography (OP) has experienced a new boom thanks to the development of digital techniques. It makes it possible to establish a statement of the condition of the painting walls and their support at the time of the acquisition campaign. This image is obtained by photogrammetry that generates a point cloud. It has many advantages. The most of them is the ability to take planimetric measurements and to analyze the reliefs by the way for example of a depth map. It is in this way a perfect complement to RAK. Digital cameras also make it possible to obtain images using other techniques such as multispectral imaging [41,42]. The fusion of the multidimensional data through a photogrammetric process offers then the opportunity to go further in the conservation analysis and the help to restoration of cultural heritage [42-44], [44]) show thus the input of successive OP acquired over time to follow the geometrical evolution of a surface.

3. Materials and Methods

3.1. *Materials*

The studied material is the lintel from the west wall of Takelot I' burial chamber, fig. (1) and its surroundings. It was cut in a soft beige and fine-grained limestone probably coming from Toura/Massara quarries [7]. Its dimensions are in its unbroken part: 1.45-1.60 m in length and ~0.65 m in height. Montet [1] already indicated, most of the building blocks of the tombs are reused stones and presented cavities that had been filled-in with "plaster" at the time of their reuse.

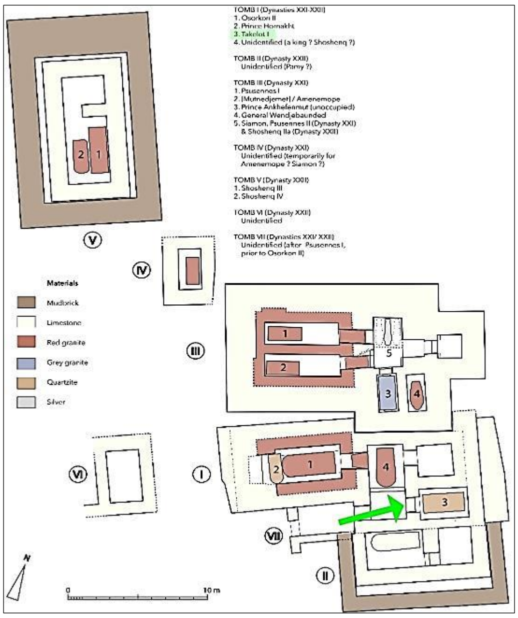


Figure (1) Shows map of Tanis' tombs; a green arrow indicates the entrance of Takelot I's tomb.

3.2. *Methods*

The camera was a Reflex Nikon D850 with an in-plant modified captor equipped with a Nikon 60 mm lens and a TG1 Phase One filter. It was hitched to a Manfrotto[c] slider and an ARCA-SWISS Core 75 Leveler that were installed on a Gitzo tripod. This assembly has allowed conserving an equal distance and a constant height and being free from the non-planar floor. A telemeter was helping to its positioning. To acquire VIS images and to make an OP, both camera-flashes have been disposed on both sides of the studied area with an about 45° angle between the light beam and the surface. The OP has been acquired according to a mosaic technic [45]. All the images have been caught perpendicular to the surface and each image has an overlap of 60% with the successive on laterally and/ or vertically. Metashape© software enables generating an ortho-rectified image by correcting the deformations induced by the optics, the weak variation to the strict normal to the surface and the relief. 24 photos have been necessary to ensure an optimal recovery of the lintel and to create the orthophotography. This software has also been used to generate the depth maps. Different lightning systems have been used to make the technical imaging, tab. (1). To make the investigations in the IR domain, the low-pass filter which is present ahead of the captor to stop IR radiations, has been removed. The whole radiation is then caught. As the camera captors are sensitive to a 360-1100 nm range [25], an 87 Wratten Kodak© filter was used to only record the radiations from 800 to 110 nm. IRfc images are obtained transferring the red layer coming from the IR image to the RVB image [46]. This is accompanied by the blue layer removal [47]. These operations allow giving a color translation of shades of grey coming from the IR file information that are not conspicuous a lot to the human eye. IRl images have been made under led lights at 610 nm that do not emit in IR domain and can be used then for photo-induced luminescence emitted in near IR domain [34]. To clarify the observations made during the technical imaging campaign, observations have been made using a field microscope. A long-distance Dino-Lite (WF4515ZTL) was the used digital microscope to make images (µVIS) at different magnifications. It is equipped with a LED light ring that emits in the visible domain and is mounted on a flexible gooseneck arm attached to a photo stand by means of a clamp. It offers x10 to x140 magnification, with built-in polarizer and internal calibration for measurements. It operates at 4 to 15 cm from the surface depending on the magnification. The flexible LED control made it possible to draw a depth map from the µOP coming from the images taken with the dino-lite. Several images were made, by a mosaic technique with a recovering of around 80 % and, for each position using all possible lighting modes (selection of the LEDs of the NW, NE, SE, SW quarters of the ring, selection of the LEDs of the upper half ring, of the lower ring and lighting with all LEDs).

Table (1) Used lighting systems

Type of lighting	Material
Direct daylight	2 camera flash Profoto B10+
UV light	2 UV led system Dedolight UV365nm
Red light for IR fluorescence	2 led system Varytec LED PAR 14x8W RGBW IP65

4. Results

4.1. *Description of the lintel*

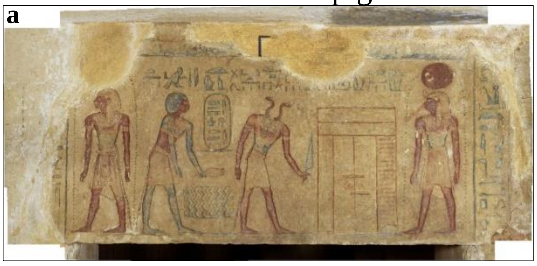
VIS image, fig. (2) shows the conservation state of the lintel and its decor. It appears to be in three parts. The main part is central, and two cracks patched with mortar that have an oblique direction separate it from two smaller blocks on its left and its right. The central and the right blocks have a general light brown ochre color. The surface aspect of the left block is beige. It is different from both others as its color is lighter and more granular. Its response under UV also is different as it has a light yellowish and clear fluorescence, fig. (3).

Figure (2) Shows VIS image of the lintel of Takelot I's tomb entrance; dimensions of the lintel in its unbroken part are 1.45-1.60 m in length and ~0.65 m in height.

Figure (3) Shows UVf image of the lintel of Takelot I's tomb entrance; dimensions of the lintel in its unbroken part are 1.45-1.60 m in length and ~0.65 m in height, the left block fluoresces in a yellowish tint.

The central and the right blocks have a similar surface aspect. They show the same yellowish and darker fluorescence under UV, fig. (4-a). Furthermore, the depth map coming from the generated point cloud from the OP, fig. (4-b) shows the recessed left block surface compared to both others. RAK image, fig. (5) reveals lots of surfacing tool marks on these two blocks thanks to the raking light coming from the bottom. These traces are mainly vertically oriented. They are larger on the right block and have a more oblique orientation. No evidence of surfacing tools traces is visible on the left block. Parts of the lintel show a polychrome that is made of blue, red and black colors. The blue color that is visible on some parts of the engravings has been lighten under lamps emitting at 610 nm and was examined in the IR domain, fig. (6). The strong observed emitted luminescence shows that the blue color is made of cuprorivaite, which is the main constituent of Egyptian blue, according to Verri [34] and Accorsi, et al[35]. The presence of this pigment appears under a purple tint on IRfc images, fig. (7). The red pigment under direct light (VIS image) takes a khaki tint on the IRfc images fig. (7). Comparing this to references such as Pichot, et al. [28] and assuming that the pigment is not mixed with any other pigment or charge, these signals would be attributed to the presence of red ochre. The observation using a digital microscope shows that the pigment layer is very thin. Darker areas that appear black on VIS an IRfc images, fig_s. (2 & 7) are mainly visible in the eyes of characters and seem to be the result of the superposition of two pigments, red ochre and a black pigment, which should be black carbon. Some brows are black because of the sole black pigment.

a



b

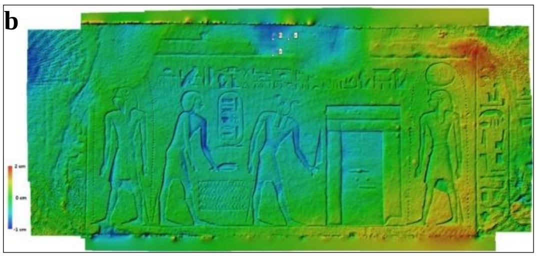


Figure (4) Shows **a.** orthophotography (OP) of the lintel of Takelot I's tomb entrance, **b.** the depth map that comes from the generated point cloud from the OP; dimensions of the lintel in its unbroken part are 1.45-1.60 m in length and ~0.65 m in height.

Figure (5) Shows RAK image of the lintel of Takelot I's tomb entrance; dimensions of the lintel in its unbroken part are 1.45-1.60 m in length and ~0.65 m in height. *The raking light lights up the lintel from the bottom and underlines the relieves such as surfacing tool marks, engravings or blisters*.

Figure (6) Shows IRl image of the lintel of Takelot I's tomb entrance; dimensions of the lintel in its unbroken part are 1.45-1.60 m in length and ~0.65 m in height. *The bright luminescence is attributed to the presence of Egyptian blue*.

Figure (7) Shows IRfc image of the lintel of Takelot I's tomb entrance; dimensions of the lintel in its unbroken part are 1.45-1.60 m in length and ~0.65 m in height. *The pink tint is attributed to Egyptian blue and khaki one to the presence of red ochre*.

4.2. *Observations of the degradations*

Different degradation features that are defined according to Collective [48] affect the lintel: gaps, lacuna, chipping, cracks, disintegration, efflorescence, white veils, chromatic degradations, and a glossy aspect. Some of the gaps, lacuna and cracks have already been filled-in by mortars in the past. Not all these degradation features are visible or discernible on the sole VIS image. The depth map and RAK images of the lintel, fig_s. (3 & 4) allow better highlighting the degradations that led to the deformation of the surface: ***)** some parts of the surface shaping and the engraving seem worn because they are not very visible, especially in the middle and in the lower part where the engraved door; ***)** the lintel surface is locally significantly degraded; it leads to the disappearance of the engraved parts and shows a strong roughness on the side parts in contact with the underlying masonry that results from a granular disintegration; ***)** the restoration mortars that fill-in the gaps are slightly set back from the surface of the stone block; they are also strongly degraded on the right upper part of the lintel because of an in-progress granular disintegration and white efflorescence; ***)** missing parts affect the mortar on the left part of the lintel and white efflorescence cover it when it is in contact with the original engraved stone; ***)** the central part of the lintel seems to be broadly less affected by the deformations even if a few blisters are locally visible on its right part. The RAK and depth map images, fig_s. (4 & 5) make it indeed possible to highlight the blisters. This phenomenon appears to be active, as the blisters are on different steps of formation, from the bulging to their bursting. The µVIS image of the blisters that have partially burst, fig. (8) shows that the exposed stone is yellowish. The surficial thin red pictorial layer (<100 µm) is on a whitish layer which locally shows a yellowish color of the exposed stone surface. It seems to be the detached part of the surficial stone. The whitish layer appears to be of the same nature as the stone and is attributed to the presence of calcite. The whole discovered part of the blisters because of the loss of the superficial materials has a shiny appearance and locally presents a residue of greyer material that could result from the combination of salts and dust. The µVIS image of the burst blisters, fig_s. (8 & 9-a) shows also a discontinuous and grey to black line between the whitish "layer" and the grey to yellow surface: it is a shadow due to overhead lighting and it indicates a disjunction that is discontinuous under the residual part of the blister. Nevertheless, it was not possible to determine the extent of this detachment in-depth. The discovered surface shows a high roughness. The micro-reliefs that are visible on the surface of the blister could be attributed to small forming blisters (appearing in a green-to-green yellowish color in the center of fig. (9-b). The discovered surface is quite bright, fig_s. (8 & 9-a); this corresponds to white spots in the image and may result from reflections on different calcite crystals faces. The excavation of the blisters often is irregular. The digging is all the more important of the layer supporting the painting no longer is present and the remains of the blister have the highest altitude, fig. (9-b). VIS image, fig. (2) shows that the entire lintel has a yellowish color and is darker in its central part. A light grey-bluish fluorescence is mainly visible in the rest-oration mortar or on its periphery; these areas show a white colour on the VIS image. Some areas of the right have a bluish grey fluorescence, fig. (10-a). A part of them is allocated to splashes and lime milk run. The other part with a rectangular design corresponds to surface cleaning tests, fig. (10-b). Surficial white parts locally appear as veils under UV in a diffuse way or in clusters. These observations under digital microscope show that these clusters are made up of relatively elongated geometrical grains. Last, the red layer has a glossy and thickened appearance, fig. (8).

Figure (8) Shows µVIS image of a blister (lintel of Takelot I's tomb entrance), the exposed stone is yellowish and The surficial thin red pictorial layer (<100 µm) is on a whitish layer that seems to be the detached part of the surficial stone.

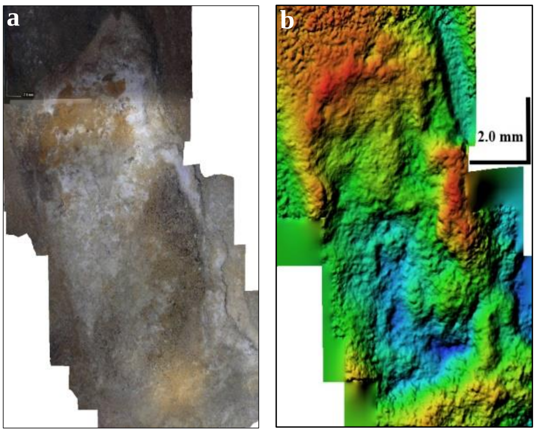


Figure (9) Shows **a.** µOP image, **b.** depth map of a part of a blister. *In the depth map image, the altitude ranges from the deepest altitude in blue to the highest in red. The discovered surface shows a high roughness. Green to green-yellowish color in the centre of the figure seems to be attributed to small forming blisters*.

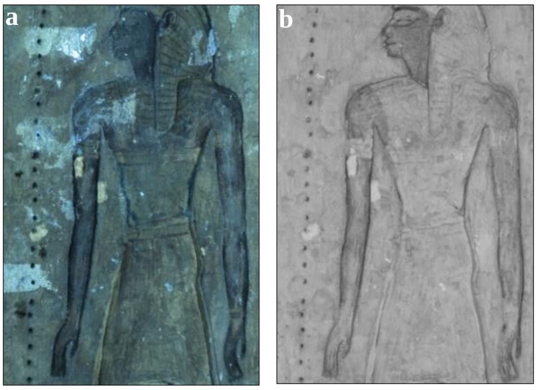


Figure (10) Shows **a.** detail: UVf, **b.** IR images of the upper part of the right figure; lintel of Takelot I's tomb entrance. *The fluorescence of splashes, lime milk run and test cleanings appears in a bluish grey tint, the exposed stone in the burst blisters has a yellowish tint. The exposed stone appears as bright in the IR image.*

2. Discussion

The scientific imaging investigation, which is an exploitation of all the acquired tec-hnical images, allows analysing the lintel surface, giving information on the pigments and a lot of information about the degra-dation patterns affecting the surface of the lintel and their possible causes.

5.1. *Surface aspect of the lintel*

The scientific imaging investigation, which is an exploitation of all the acquired technical images, allows analyzing the lintel surface state, giving information on the pigments and a lot of information about the degradation patterns and their possible causes. RAK, depth map, and UV documentations allow clearly revealing the relationships that exist between the central and the right blocks of the lintel. The central and the right blocks constitute two parts of the same stone because the engravings seem to be connected. More, they both show tool marks. The surfacing tool marks can be well-characterized thanks to the OP and the RAK. They were made using a tool as a chisel that was 0.7 to 0.8 cm large. They seem to have been made bottom-up and to have a small extension of 1 to 2 cm length. The surface of the left block has neither the same color nor visible tool marks. Last, the images comparison of Pernette Montet's survey from 1945, fig. (11) and the lintel surface state in 2020, fig. (2) shows that the engravings of this block are no more visible. More, its surface is recessed compared to both others, fig. (4-b). Last, its color looks like the beige color of the exposed stone that is visible inside the lacuna from the central block. Its fluorescence under UV also corresponds to the yellowish and light fluorescence of the exposed stone and can be partly due to the fluorescence of natural calcite from the limestone. Thus, the left part of the limestone seems to have lost its surface since Pernette Montet' survey [1]. Indeed, VIS images have been compared to fac-similes drawings made in 1945 by Pernette Montet, the eldest daughter of the discoverer of the tombs, fig. (11).

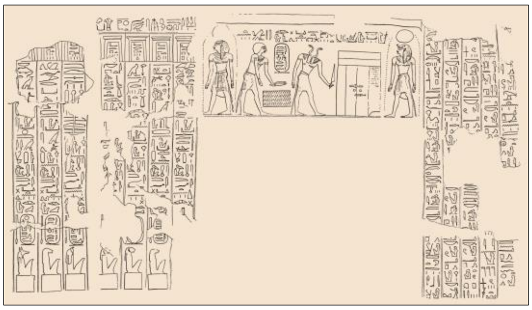


Figure (11) Shows Pernette Montet's survey of the lintel of Takelot I's tomb entrance (1947).

Montet's books [1-3] contain indeed numerous charts that give some information on the conservation conditions of the tombs when they were discovered. It is then possible to visualize some degradations and interventions that have appeared since the facsimiles were made. As these drawings were mainly intended to document the preserved decoration itself, they necessarily don't map all the visible forms of degradation. These observations are therefore only indicative and partial. However, they show that the restoration mortar covers areas that were still visible after WWII. The assembly also highlights the degradation already present at the upper part of the lintel. These observations are in favor of an origin of degradation from the slabs that forms the ceiling of the tomb. This is in accordance with [6] who noticed infiltration issues and testifies to refurbishment works to stop them in 1987: the observed degradations result from infiltrations and salt migrations and mainly occurred because of a lack of protection of the tomb roof paving that was not originally designed to be directly exposed to rainfall. Thus, the scientific imaging goes in this way as the lintel locally presents a light grey-bluish fluorescence near the restoration mortar that is the same in the mortar. This fluorescence comes from chloride and sulphate based hygroscopic salts, with reference to [48, 50] and VIS, RAK and depth map images reveal the granular disintegration affecting the left block surface [49]. Last, the whole surface of both the other stone block has a yellowish appearance and a hardness that could be due to a layer of epigenetic gypsum combined with soiling and an aged polymer resin. In this case, the resin may have penetrated during its application through cracks that affected the blister before its bursting. This resin would have then partially tinted the most superficial part of the discovered stone before it was visible. The partially detached part of the stone under the pigment layer is white. As another important degradation pattern, blisters affect the lintel at different evolution steps. Their formations are supposed to be the consequence of crystallization-deliquescence cycles of soluble salts beneath the surface [48]. Due to the repeated wet-dry cycles, the salts lead to the formation of a vesicle and then to its bursting with a loss of material and a hollowing out of the affected area [16]. The edges of the resulting holes show that the degradation leads to the separation the surficial part of the stone on which stays the pigment layer from the rest of the lintel. If IRfc gives information on the nature of salts as sulphate or chloride based-compounds, UVf image also gives information on the nature of these secondary materials, fig. (3) such as the surficial white veils that appear to be mad of salt crystals of undetermined nature.

5.2. *Nature of the pigments*

A lot of studies on the identification of the pigments are generally performed using laboratory techniques including X-Ray diffraction, X-ray Fluorescence, FTIR, Raman, SEM-EDS, on many samples, e.g. Al-Emam, et al. [51], David, et al. [52], Marey & El-Badry [53], Marey & Abo El-Yamin [54] and Uda, et al. [55] or portable ones, e.g. Pagès-Camagna & Raue [56]. Nevertheless, Cosentino [27], Pichot, et al. [28] and Hayem-Ghez [33] as examples, experienced another way using imaging techniques and more precisely scientific imaging. Even, scientific imaging cannot claim the exact nature of pigments, this easy-to-use, non-destructive and portable technique allows formulating strong hypotheses about it using a reference database if we consider that a single pigment layer or a simple mixing of two pigments was applied on the support. It revealed the presence of Egyptian blue, red ochre and carbon black on the lintel. Thus, the strong observed emitted luminescence in the IR domain under lamps emitting at 610 nm shows and Tanis historical context, lead to conclude that the blue pigment is cuprorivaite. More, it helped to discover pigments traces that were not visible to the naked eye and made it possible to reappear altered or disappeared compositions and to locate these traces precisely.

5.3. *Traces of past restorations*

The brownish color of the entire lintel that is visible on VIS image may be due to the presence of an aged and yellowed resin which could be associated with epigenetic gypsum and soiling, cf. [49]. The brownish colour on the central and on right blocks could be attributed to the soiling and a consolidant treatment that was applied during the 80's [49], as it does not give any fluorescence, has a dark appearance under UV and shows shine effects under RAK as on the character on the right of the scene (face, arm). The glossy and thickened appearance of the red layer is due to an applied resin on the surface and the presence of epigenetic gypsum [12]. The resin seems to give the partially yellowed appearance of the discovered stone material. This product may have been accelerated the degradation process, because of the presence of soluble salts [57]. The restoration mortars do not fluoresce and appear black under UV. The limit between the restoration mortar with the left block (yellowish fluorescence) and the lintel (yellowish and darker fluorescence) is clear; these mortars consist mainly of carbonated lime [57] and may contain moisture and maybe a contemporary polymer resin too. The observed splashes and lime milk run that are visible under UV probably occurred during a restoration intervention, as evidenced by the lengthened or droplet shapes of certain areas that are mainly located on the arms. It could correspond to projections of lime when the mortar was applied as a plugging in the upper parts of the lintel. The other parts with a rectangular design correspond to surface cleaning tests.

3. Conclusion

The technical imaging, which is a real non-destructive and contactless technique, was performed on the lintel of the West wall of Takelot I's tomb. Because of the realized investigations under different wavelengths, the combination of images, and the acquisitions from the micro to the macro-scale, a lot of information have been acquired on the materials, the degradation and conservation issues without any sampling. This confirms the important input of this in field and easy-to-use technical set as a precise documentation and analysis tool. It produces a precise documentation, and it gives a precise conservation state of the observed object that is also a dated reference. It produces information on the presence and the materials nature: presence of resins, nature of the surficial materials pigments such as Egyptian blue, red ochre or carbon black, restoration materials, soluble salts (chloride, sulphate-based compounds). It helps to identify the origin of the alterations affecting the lintel that come from rainfall infiltrations and soluble salts migration. It helps also to identify and localizes restoration materials, alteration patterns and their specific activities such as some blisters that are visible at different stages of formation. It also facilitates the mapping of previous interventions and helps to locate future operations. This kind of study will also help to determine the needs to make some onsite physical-chemical analyses, to limit the sampling and to locate the sampling areas. Last, it will help the restorers to plan and implement the next restoration campaign.

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