Egyptian Journal of Archaeological and Restoration Studies (*EJARS*)
An international peer-reviewed journal published bi-annually
www.ejars.sohag-univ.edu.eg

Original article

THE COFFINS OF 'Irwt: AN ARCHAEOLOGICAL AND CONSERVATION STUDY

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Article info.

Article history:
Received: 16-1-2024
Accepted: 28-8-2024
Doi: 10.21608/ejars.2025.434902

Keywords:
Coffin
late period
Irwt
Saqqara
Consolidation
Assembly
Treatment

EJARS – Vol. 15 (1) – June 2025: 59-68

Abstract:

One of the most beautiful coffins from the 21st Dynasty is the coffin of Lady "Irwt", which was discovered by the mission of the Egyptian University of Science and Technology working in the eastern Tabet Al-Geish area in Saqqara during the 2022 season. This unique coffin was found directly south of the temple of Hathor, which was partially uncovered in the 2021 season and fully uncovered in the 2022 season. The coffin was first discovered as a structure made of several reused stones from adjacent buildings dating back to the Old and New Kingdoms, some of which were taken from the previously mentioned 18th dynasty temple. The stone coffin was built in the form of a small tomb, inside of which a rectangular wooden box with a lid was found, decorated with vertical lines in blue, red, and black. It was possibly divided in this way so that it could later be decorated with depictions of the four sons of Horus, in addition to some spells from the Book of the Dead, but it was incomplete. Inside this box was a rectangular coffin, with a human-shaped lid and beautiful, vibrant colors. The offering formula (ḥtp di nsw) and the name and titles of the owner of the coffin, named "Irwt", including her most important title "The Beautiful Old Lady", were inscribed on the box and on the inner coffin. The condition of the coffin, box, and the stone coffin was not good, so necessary conservation work was carried out by the mission's accompanying conservation team. The parts were tied together and the colors were fixed to reach their current state. Samples were taken and analyzed to determine the type of wood used and the colors. The mummy was found inside the coffin in a poorly preserved condition, with half of its lower part eaten by varies insects. Through various scientific *examinations to determine the materials used in the coffin's manufacturing, as well as to determine the condition of both the coffin and the lid, using scanning electron microscopy (SEM) and light microscopy (LOM) to identify the type of wood used, which is local sycamore wood, and using X-ray diffraction (XRD) to examine the colored materials used in the coffin, it was found that the imaging ground and white color were made of calcite, gypsum, and dolomite, hematite for red, malachite for green, and carbon for black. Additionally, Fourier-transform infrared spectroscopy (FTIR) showed that animal glue was the coloring agent. Through the previous stages, the appropriate method for conservation was applied according to the coffin's condition, including mechanical and chemical cleaning stages, followed by consolidation, completion. And preserve at in main store of the Supreme Council of Antiquities in Saqqara.*

1. Introduction

This coffin is one of the most important coffins discovered in Saqqara. It dates back to the 21st dynasty and belongs to a wealthy lady from that period. This is evident from the burial process, as she was buried in three different stone and wooden coffins. Additionally, a large number of high-quality linen layers were used to wrap the mummy, and we know that this type of linen was expensive and only affordable to the wealthy at that time. The fact that the coffin of Lady "*Irwt*" was buried directly next to the temple of Hathor indicates her importance and status in her society at that time. The area where the coffin was found is called the "Tabet Al-Geish east", which was the headquarters of a military battalion. This area is located south of Saqqara, north of the funerary complex of King Pepi I. Coffins held significant importance in ancient Egypt, as they were used to bury the deceased to preserve the mummies from damage or destruction if they were buried in the sand without a coffin. This ensured a good afterlife for the deceased in the next world. We cannot ignore the fact that the coffin became an important industry that involved not only the deceased and their family, but also the entire community. The process that led to the construction of the coffin and, in a second phase, its decoration and "architectonization" [1], represents a cultural dynastic fundamental for the very survival of ancient Egyptian society. Moreover, a broad scale of coffin reuse was confirmed during the 21st dynasty [2,3]. This aspect of reuse and recycling should not

be underestimated, and it opens up a range of new considerations about the social and economic value of funerary art within Egyptian society. In parallel, there has been a great deal of activity in recent years in the study of coffins in museum collections [4]. A deeper understanding of these objects from a symbolic and religious standpoint, as well as from the perspective of their construction and decoration techniques, will also open up new perspectives for their conservation. Egyptian funerary structures always revolved around two sets of concerns: while intending to create a magical framework for the protection of the body, they also aimed at the social and cosmic integration of the deceased. Arising from the close connection with the representation of the mummy, anthropoid coffins soon absorbed a rich mythological imaginary conected with the constellation of the mother, the mother goddess of the sky who supported the birth of Osiris, and continuously developed, integrating larger and more complex sets of beliefs, reflecting the increasingly bold use of coffins in funerary rituals. It was this complex set of beliefs that portrayed the coffin as a body container and, at the same time, a microcosm where the introduction of the deceased into the realm of eternity was meticulously depicted [3]. Despite their archaeological significance, the study of Egyptian coffins remained largely overlooked throughout much of the 20th century. Dr. Andrzej Niwinski [5], Dr. John Taylor, and Dr. René van Walsem figure among the first authors to begin the scientific study of Egyptian coffins. Dr. Nivinski's notable contribution to the perception of the yellow coffin as an extremely valuable documentary corpus speaks for itself. His comprehensive catalog of objects shows how the distribution of Egyptian antiquities across the world presents serious problems for systematic examination of the coffins. Dr. John Taylor, on the other hand, has focused on the coffins of the 22nd-25th dynasties, thus greatly expanding the documentary corpus for systematic analysis. But Dr. René van Walsem's views on the architectonization of coffins have contributed greatly to revealing the importance of the conceptual framework for understanding the development of coffin decoration as a coherent system of information, exploring the limits of its own complexity. His methodological procedures, based on a unified terminology and description, provide a solid foundation for describing the coffins [3]. We have recognized how important it is for further research on Egyptian coffins, especially those dated to the 21st dynasty, to ground the description of these objects in theoretical concepts [3]. Dr. Rune Nyord, Dr. René van Walsem, and Dr. Kathlyn Cooney have each developed new conceptual frameworks or methods for investigating Egyptian coffins [6]. Stylistically, the private coffins of the early Second Intermediate Period have little to distinguish them from those of the later Twelfth Dynasty. However, a particular burial style became fashionable during this time for members of the royal family and high officials. Most examples were found around the pyramids of the kings of the 12th dynasty at Lahun, Lisht, and Dahshur. More recent research suggests, however, that some burials should be assigned to the end of the 12th dynasty, while others undoubtedly belong to the 13th dynasty [7]. The type of burial is rectangular coffins, of very good quality. They have no object friezes or representations associated with the coffins of the later 12th dynasty. Most of these coffins are intentionally open to display the body, and were made from fine-textured cedar wood. In some examples, the decoration consisted only of the eye panel and strips of gold foil at the edges. Others had gilded text bands in the traditional positions, but no false door was represented. Some of the court coffins had an arched lid, similar to the so-called house coffins of the Early Dynastic Period and the Old Kingdom. The inner coffin came in human form. The masks and collars of these were richly inlaid and sometimes, as in the burial of *Senebtisi* at Lisht, the entire coffin was covered in gold leaf over a coating of linen and plaster. Special attention was paid once the inner coffin was opened, once the mummy was placed inside. A series of metal hooks set in sockets at the foot end of the coffin and engaged metal pivots fell into a slot, effectively sealing the coffin. As these protective measures were hardly to be thwarted by determined tomb robbers, one cannot help but suspect that they were there, tempted to remove the burial items responsible for the burial [7]. From c. 1650 BC, the entire Delta and the northern part of Upper Egypt came under the control of the Hyksos, while the southern part of the country retained a precarious semi-independence under the Theban rulers of the 17th dynasty. Most of the Hyksos seem to have adhered to Canaanite burial practices, and so evidence of coffin development during this time mainly comes from the Theban area. Some of the rectangular coffins are exceptionally long and narrow, with a strongly arched lid (such as the coffin of Senebni at Qurna, Cairo CG 28029) [7]. The external decoration was painted on a black background. It includes the eye (surrounded by a breast-shaped frame) and up to ten columns of text on each of the long sides [7]. Although rectangular coffins remained in use, many Thebans of this time were buried in a type of human-shaped coffin, known as a rishi coffin. These are easily recognizable, both by their squat form and by the characteristic decoration of the lid, which consists mainly of a huge pair of wings covering the body from shoulders to feet (such as the *rishi*-coffin of *Reri* at Draa Abu el-Naga, Metropolitan Museum of Art). It is this construction that shielded the deceased through the protective wings of Isis and Nephthys, which gave rise to the modern term "rishi coffin" derived from the Arabic word for "feather". Additional protection was provided by the vulture Nekhbet and the cobra Wadjet [3], which are usually depicted on the chest, while the offering formula was generally inscribed along the center of the lid between the two wings. On *rishi*-coffins, the deceased is usually represented wearing the royal Nemes headdress, regardless of their rank in life [7]. Some of these coffins were assembled from small pieces of wood, but others were hollowed out from tree trunks. Most were of mediocre workmanship, but even those of the kings and queens of the seventeenth dynasty buried at Draa Abu el-Naga were very finely finished, with a layer of gold plates and inlaid eyes (such as the gilded rishi coffin of King "Nub-kheper-Re Intef", Dra Abu-Naga, British Museum, 6652) [7]. Most private coffins of the eighteenth dynasty were found in Thebes, and at the beginning of this period two main types were distinguished: coffins in human-shaped form with *rishi*-decoration, and rectangular coffins representing the last manifestations

of Middle Kingdom traditions. These coffins had flat or arched lids and were usually decorated with geometric patterns, figures of Isis and Nephthys, and Anubis as a jackal, but they were of poor quality, clumsily painted in bright colors. Both remained in use until the reign of Thutmose III, but by this time an alternative had been developed, a new type of human-shaped coffins, usually made of sycamore boards but occasionally excavated, which soon achieved great popularity [7]. This classic New Kingdom coffin, examples of which were already known at least in the reign of Thutmose I, was the product of a fusion of the main elements of the older mummy-shaped type and the rectangular coffins. The lid, still copying the traditional appearance of the mummy, was decorated with a three-part wig and falcon collar, but it was flatter and less rounded than the lid of the human-shaped coffins of the Middle Kingdom. The basin or lower half of the coffin was generally quite deep, with the sides almost vertical, and the base was flattened in the middle, as these coffins were buried on their backs, not on their sides as in the Middle Kingdom. Part of the decoration on the lid and practically all of that on the basin was derived from the decoration of the rectangular coffins, with the offering formula or prayer to Nut inscribed along the center. Four vertical inscription bands appeared on the side, and these were arranged to connect with the crossbars of the lid (as with the coffin of Ahmose's son of *Nakht*, Dra Abu el-Naga, early eighteenth dynasty, Metropolitan Museum of Art) [7]. Among other stylistic developments of this time, we can note the tendency for the coffin form to copy the mummy with increasing accuracy. The black coffins show this clearly, as they usually have better proportions than earlier white-painted types, some examples of which were very clumsily shaped. The representation of crossed hands on the lid is first attested on private coffins in the time of Hatshepsut (Cairo J. 66.197), but they only occur sporadically before the 19th dynasty [7]. During the 18th dynasty, most private individuals appear to have been provided with a single coffin and mummy mask, but this rule was not immutable. The tombs of Yuya and Tuya in the Valley of the Kings reveal that for high-ranking individuals, groups of up to four coffins were available [7]. Relatively few coffins can be attributed to the nineteenth and twentieth dynasties. Many of the tombs of high officials are likely still waiting to be discovered in the Memphis necropolis, so we primarily rely on material from Thebes. Unfortunately, the Ramesside tombs there have suffered so badly at the hands of robbers that very few well-preserved coffins have survived. The main exceptions, however, are those of *Sennedjem* and his family, discovered in an intact tomb in Deir el-Medina in 1886 and now divided between Cairo, New York, and Berlin [7]. Anthropoid coffins were now the norm, although sometimes a wooden shrine-shaped catafalque was provided (that of Chons, son of *Sennedjem*, being perhaps the best-preserved example). The old black-painted coffins continued to be used into the reign of Ramses II, but they were gradually replaced by the new type introduced towards the end of the 18th dynasty. These were painted in bright colors, mainly red and blue on a yellow ground, and coated with a clear varnish which darkened with time, giving the decoration a predominantly yellowish tone [3]. The lids were decorated with a winged nut, while the spaces between the text bands began to be filled with scenes of the deceased offering gifts to gods, episodes from the burial ceremonies, and other depictions reminiscent of tomb paintings. The exterior of the basin was generally decorated with figures of Thoth and the Sons of Horus, as in the 18th dynasty. Some changes in details are notable. Crossed hands became a standard feature, and the clenched fists often hold religious emblems; the flower collars usually cover the forearms, yet the hands protrude through them in a rather implausible way. The hoods are a break with formal tradition, as instead of the better Ramesside coffins having the type of headdress worn by the fashion-conscious nobleman and his wife of the time. Women opted for a heavy wig with straight masses of hair brought forward over both shoulders and held together with horizontal bands, while the type worn by men consisted of two lateral "flaps" of hair swept back around the shoulders and then folded forward over the chest [7]. The next major change in coffin design is believed to have been made towards the end of the twentieth dynasty. A number of very fine Theban examples from this period have survived (such as the coffin of *Nesamun*, Thebes, reign of Ramesses XI, Leeds City Museum; D 426.1960) [7] and these show important developments. The normal clothing design goes out of fashion and the emphasis shifts to portraying the deceased as an idealized divine being, mummified, with the three-part wig, rolled Osiris beard, and arms crossed on the chest. The inscription bands on the lid increase in number and no longer occupy the traditional positions of the main "mummy bandages". They now simply serve as borders for the vignettes and it is noted that they no longer continue onto the basin - the connection between the two halves of the coffin was thus broken. The exterior of the basin carries a horizontal strip of vignettes with a frieze or inscription above and below. The traditional motifs (such as the Sons of Horus) continue to appear, but over time they were gradually reduced in prominence and either restricted to one end of each side or completely eliminated as new scenes began to be added. The mummy board, which remained as a standard part of the ensemble, now became practically a copy of the coffin lid, with bands and colorful figure scenes [7].

1.1. *Discovery and description of Ỉrwt* coffins

One of the most beautiful coffins from the 3rd Intermediate Period is the coffin of the Lady "*Ỉrwt*", which was discovered by the mission of Misr University of Science and Technology, led by Dr. *Ahmed Mostafa Osman*, working in the eastern Tabet Al-Geish area at Saqqara during the September-October 2022 season. This unique coffin was found near the south wall of the temple of Hathor, which was partially uncovered in the 2021 season and fully uncovered in the 2022 season. Firstly, discovered a stone room, made of several reused stones from adj-acent buildings dating back to the New Kingdom, fig. (1-a & b). Some of the stones may have been taken from the previously mentioned 18th dynasty temple. This stone room was built in the form of a small tomb, measuring 235 cm in length, 113 cm in width, and with a height of 60 cm. This stone room was uncovered in layer "F#1051" after removing the surface layer "F#1000". Inside the sarcophagus, a rectangular wooden box (195×60×48 cm.) with a lid (made of sycamore wood) was found, decorated with vertical lines in blue, red,

and black, fig. (1-c & d). It was possibly divided in this way so that it could later be decorated with depictions of the four Sons of Horus, in addition to some spells from the Book of the Dead, as was common in most coffins of that period. How-ever, unfortunately, the decorations were incomplete. the wooden lid of wooden coffin came with vaulted lids and four corner posts; its measuring is 195×60×48 cm. Inside this wooden lid was a rectangular coffin with a human-shaped lid, decorated with beautiful and vibrant colors and in good condition, which became clear after conservation. Its measurements are 178×30×30 cm., fig. (1-e). The offering formula (*ḥtp di nsw*) and the name and titles of the owner of the coffin, named "*Irwt*", including her most important title "The Beautiful Old Lady", were inscribed on the box and on the inner coffin in black ink. The condition of the coffin, box, and the stone room were not so good, so necessary conservation work was carried out by the conservation team of the Mission. The wooden parts were tied together and the colors were fixed to reach their current state. The mummy was found inside the coffin in a poorly preserved condition, with half of its lower part decomposed by Insect infestation. However, the upper half was wrapped in many layers of well-crafted linen, indicating the wealth and social status of the lady in her time. As for the pieces used to construct the stone coffin, they were dismantled and the engraved parts were restored.

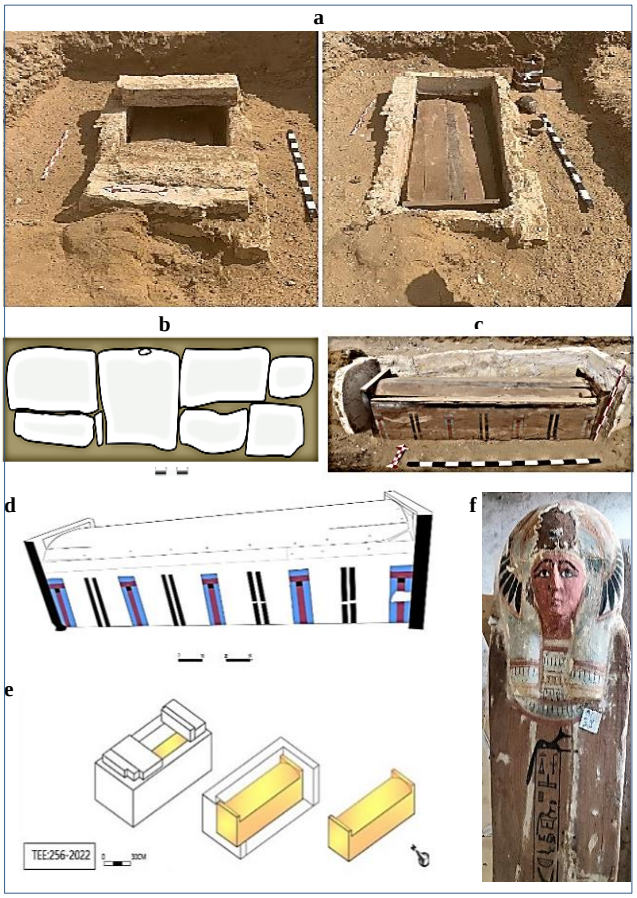

Figure (1) **a.** the sarcophagus of *Irwt*, **b.** section of the southern side of the sarcophagus, **c.** the coffin within the box, **d.** drawing of the box, **e.** drawing of the sarcophagus and box as found, **f.** the wooden coffin

1.2. *The texts*

The wooden coffin lid was not adorned with any writings except for one textual strip from top to bottom, containing the formula "*ḥtp di nsw*", which roughly translates to "The Yearning of Women". It included mention of various offerings along with titles of the coffin's owner, and concluded with her name. The text was written in black ink without any embellishments or other colors, indicating that the burial process was intended to be done quickly, leaving little time for the coffin to be adorned with protective symbols and religious spells incantations to safeguard the deceased. Therefore, they settled for writing the offerings formula, encompassing all the offerings beloved to this lady, and it ended with her name.

1.2.1. Text of the wooden lid, fig. (2)

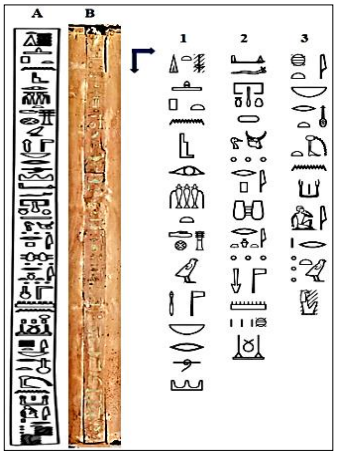

Figure (2) text of the box

ḥtp di nsw ḥtp n Wsir ḥntt Ḏdw nṯr ꜥ3 nb r3-st3w di.f prt-ḫrw irp irtt snṯr mnḫt šs iḫt nb(t) nfrt wꜥb(t) n k3 Irwt.

An offering offered by the king, an offering to Osiris in front of "Jdedw" [8,9] the great god, the master of "Rastau"(Necropolis) [10]. He offers offerings, wine, milk, incense, clothes, linen, and all things beautiful and pure to the spirit of "Irwt".

1.2.2. Text of the wooden coffin, fig. (3)

The text written on the coffin in black ink came in a single vertical column, just as it appeared on the box.

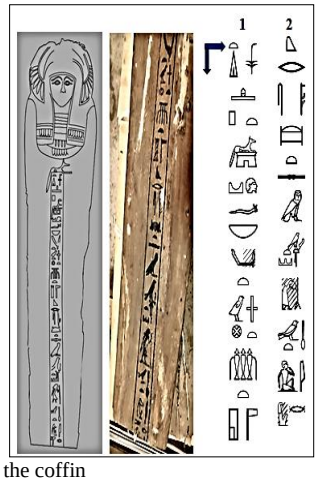

Figure (3) text of the coffin

ḥtp di nsw ḥtp (n) ʾInpw tp(y) ḏw.f nb ḏsr(w)t imywt ḫntt sʒḥ nṯr ḳrst m imntt iwt nfrt ʾIrwt.

An offering offered by the king as an offering to Anubis, who residing atop his mountain, the lord of the sacred beings in front of the deity's shrine. May the beautiful old lady be buried in the West.

1.2.3. Comment about the two texts

The first text, adorned at the top of the box, is dedicated as an offering's formula from the king to Osiris, and among his titles is the Great God, Lord of Rastau. Then various types of offerings are presented, including wine, milk, incense, clothing, alabaster, and all beautiful and pure things for the spirit of *ʾIrwt*. As for the second text, it adorns the top of the coffin containing the mummy with the offering's formula presented by the king to the god Anubis. It then lists his important titles, including the one who resides above his mountain, the lord of sacred places, present in front of the deity's shrine. Then comes a prayer for the beautiful old lady "*ʾIrwt*", perhaps to be buried in the west. This is what every deceased person wishes for.

2. Condition Assessment of Wooden Coffin

During excavations in 2022 at the eastern site of Tabet Al-Geish in Saqqara, a wooden anthropoid coffin of a mummy dating back to the 21st Dynasty was discovered by the joint mission of the Misr University for Science and Technology and the Supreme Council of Antiquities. The coffin was found in a stone room built of reused limestone from the nearby Temple of Hathor, which had inscriptions and hieroglyphic writings dating back to new kingdom, Inside the lid, there is a wooden anthropoid coffin bearing the same hieroglyphic band on the lid and the coffin, belonging to a lady from the 21st dynasty. The coffin has suffered from various aspects of deterioration due to its burial's proximity to the ground floor surface and the absence of a stone base underneath it. This direct contact with the ground exposed the coffin to different types of deterioration factors. The wooden coffin and wooden lid also experienced biological deterioration resulting from insects' attacks on the wooden coffin or the mummy inside. This is evident through the gaps spread on the coffin's surface or the dilapidated parts of the coffin, which were subjected to multiple insect attacks from various types of insects, the insects attacked the lower half of the mummy, leaving only remains of bone and linen wrappings, fig. (4-a). In addition to insect attacks, the coffin was also attacked by microbiological agents, such as fungi and bacteria, which aspect in the form of spots on the wooden coffin or the wooden lid. The non-sealing of the stone chamber of the coffin and the lid and the wooden cover led to the coffin being affected by various aspects of physical, chemical and biology deteriorations. The wood has decayed and darkened, and small wood chips can easily fly off as this is a feature of microbiological deterioration such as soft rot decay or brown rot while the brittle woody outer layer can be easily scratched [11]. This confirms the fragile nature of deteriorating wood, and it is likely that the losses over time are due to the severely deteriorated condition of the wood [12]. The shrinkage of the wood resulted in many transverse and longitudinal cracks, some of which penetrate the thickness of the wood. It is also noted that some dry parts of the coffin and the lid have fallen off due to this deterioration, fig. (4-b & c). The base of the wooden coffin has separated from the body, and the wooden structure of the lid and the coffin has also separated due to exposure to high levels of temperature and relative humidity fluctuations. The coffin body and lid also have many cavities and voids [13]. collapse of the color layer, loss of cohesion, and falling off upon contact. The color layer separated into many pieces, with the color peeling off in several areas. The presence of fluorescent salts was observed at the base and sides of the coffin and the lid as a result of direct contact with the ground in the area [14].

Figure (4) damage aspects of the wooden coffin; **a.** resulted from the insect attack, **b.** flaking gypsum prepare and color layers from the surface of the coffin and longitudinal separation in the prepare and color layers, **c.** cracks and deep cracks on the coffin's surface caused by expansion and contraction cycles and salts efflorescence.

3. Materials and Methods

Before beginning conservation of the wooden coffin and wooden lid, a thorough scientific examination and analysis of the coffin's condition were necessary to identify the weaknesses in the coffin. Samples were carefully selected during the conservation work from areas that have no aesthetic value for conservation and from areas suffering from deterioration. This allowed for the development of a method for conservation based on the principles and standards used in conservation of archaeological wood, particularly ancient coffins dating back to the ancient Egyptian era. Fallen samples were collected from around the wooden coffin without affecting its mechanical properties to conduct an integrated scientific study before conservation operations. Wood samples, samples of the preparation layer, and the red, white, black, and blue colors of the wooden coffin and the wooden lid were examined using various scientific methods [15].

3.1. *Light microscope*

The samples were studied using light microscopy in the laboratory using an Olympus BX40 optical stereoscope, and were recorded with a digital camera at 40-60X magnification to study their surface. LOM can provide information on the physical condition of the coffin as well as the extent of the bonding between the components of the coffin in terms of wood, preparation layer and color layer.

3.2. *Scanning Electron Microscope (SEM-EDX)*

Wood samples, preparation, and coloration layer were analyzed using a Jeol JSM-6400 LV scanning electron microscope (SEM) equipped with an Oxford energy-dispersive X-ray (EDX) system, detector model 6587. For analysis the sample was plated with gold.

3.3. *X-ray diffraction (XRD)*

The selected samples were analyzed by X-ray diffraction (XRD) using a Philips PW 1840 diffractometer, and the patterns were triggered with nickel-filtered Cu Kα radiation (λ = 1.54056Å) at 40 kV and 10 mA. Diffractograms were taken between 5.025 and 73.96 degrees.

3.4. *Fourier transform infrared spectroscopy (FTIR)*

The binding medium was studied by fourier transform infrared (FTIR) spectroscopy. The samples were analyzed as KBr pellets by Bruker FT\IR – 460 plus. 0.5 mg of a powder sample was dispersed and ground into approximately 70 mg KBr and pressed into granules of less than 10 mm.t/cm^2. The KBr pellets were screened for powder samples between 4000 and 400 cm^{-1} with a resolution of 4 cm^{-1}. Spectra were obtained between 1000-4000 cm^{-1}

3.5. *Identification of the wooden coffin*

The wood sample from the coffin chest was dried and brittle. It was embedded in polyethylene glycol (PEG) and cut using a rotary microtome. A thin section (15-20 mm) was obtained in three main anatomical directions, transverse (TS), transverse (LS) and radial (RLS). Anatomical sections were observed by transmitted light microscope (Olympus BX40) with a digital camera at 40-60X magnification.

4. Results

The utilization of various methodologies in the present investigation has yielded numerous outcomes that can be succinctly summarized as follows:

4.1. *Identification anatomical features of the wooden coffin by (L.O.M)*

Microscopic investigation indicated that the polychrome wooden coffin and lid were made of sycamore wood, which is one of the local woods and commonly used in the manufacture of 21st dynasty coffins [16]. Transverse section **(TS)**, fig. (5-a) vessels solitary or in radial multiples of 2 to 4 and axial parenchyma in bands (up to 20 cells wide), scanty Para tracheal or vasicentric. Tangential longitudinal section **(TLS)**, fig. (5-b) rays of two distinct sizes, 1-4 seriate, and 5-14 seriate, Laticifers observed in rays. Radial longitudinal section **(RLS)**, fig. (5-c) body ray cells procumbent with one to 4 rows of upright and square marginal cells.

Figure (5) microscopic examination of a coffin sample, especially sycamore wood. the examination distinguishes the anatomical features of the sample through cross-section, tangential longitudinal section, and longitudinal radial section analysis.

4.2. *Identification of organic binding media by (FTIR)*

Arabic gum was identified as the binding agent employed for all the pigmented materials utilized in the inscriptions, writings, and decorations on the lid and the coffin [17], tab. (1) & fig. (6). Fourier-transform infrared spectrometry (FTIR) analysis was conducted to identify the organic binding media, with samples from the coffin's red colour [18].

Table (1) Wave numbers and functional groups of coffin sample and *Arabic Gum*

No	Function group		Sample wave number	Arabic Gum
1	O -H	Stretching bands	3693	3600-3200
2	C- H	Stretching bands	2950	3000-2800
3	C=O	Stretching bands	1735	1300-900
4	C=O	Stretching bands	1628	1600-1800
5	C=C	Stretching bands	1415	1300-1500
6	C -H	Bending band	1425	1480-1300
7	C-O- C	Stretching bands	1165	1000-1200

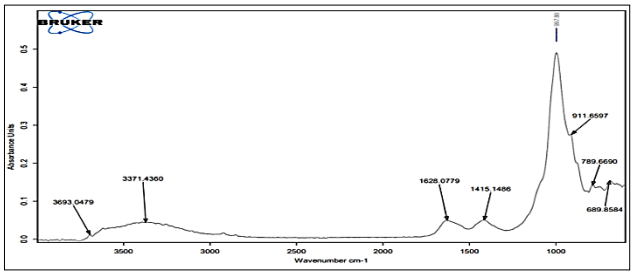

Figure (6) FTIR spectra of the coffin samples showing the bonding of paint layer and plaster.

4.3. *XRD analytical results*

X-ray Diffraction (XRD) analysis revealed that the ground layer and the white pigment consisted of calcite, gypsum, and dolomite. The red pigment was identified as hematite, the green pigment as malachite, and the black pigment as carbon [19]. By examining pigment samples obtained from wooden coffins at the National Research Center in Cairo, researchers successfully determined the composition of the ground layer as well as numerous pigments employed in the inscriptions and decorations of the wooden coffin. Analysis a sample that fell from *the ground layer* using x-ray diffraction, it was found that it is mainly calcite Ca (CO_3) mixed with quartz SiO_2 in addition to dolomite Ca Mg $(CO_3)_2$, thus forming the ground layer to hide wood defects and prepare the surface of the coffin for the inscriptions and decorations on its surface, tab. (2) & fig. (7-a). Furthermore, XRD analysis *of white pigment*, tab. (2) & fig. (7-b) revealed that the analyzed sample contained crystalline phases of calcite Ca (CO_3), quartz SiO_2, and gypsum ($CaSO_4$ $2H_2O$), which are indicted to the ground layer of the wooden coffin. *Red pigment*; according to the XRD analysis, tab. (2) & fig. (7-c) hematite (Fe_2O_3), chabazite Cu

K, and birnessite Ba (Mn_2O_4)(H_2O) were identified as the components responsible for the red pigment used in the inscriptions and decorations of the wooden coffin. Hematite is one of the iron compounds that were used extensively in ancient Egypt to obtain red pigments for various colored archaeological finds. *Black pigment*; based on the XRD analysis, tab. (2) & fig. (7-d) the black sample from the wooden coffin contains crystalline phases related to graphite (C), birnessite ($NaMnO_2H_2O$) and chabazite (CuK (AlSiO)), which are components of the ground layer. *Green pigment*; XRD analysis of the green pigment, tab. (2) & fig. (7-e) showed the presence of calcite ($CaCO_3$), quartz (SiO_2) and malachite ($Cu_2CO_3(OH)_2$) that was used for green color.

Table (2) X-ray diffraction results of samples taken from ground layers, paint layers

No	Samples	Compounds
1	Ground layer	Calcite $Ca(CO_3)$ mixed with Quartz SiO_2 in addition to Dolomite $CaMg(CO_3)_2$
2	White pigment	Calcite $Ca(CO_3)$, Quartz SiO_2 and Gypsum $CaSO_4.2\,H_2O$)
3	Red pigment	and Birnessite $BaMn_2O_4.H_2O$ Hematite Fe_2O_3, Chabazite Cu K
4	Black pigment	Graphite C, Birnessite $NaMnO_2H_2O$ and Chabazite CuK(AlSiO)
5	Green pigment	Calcite ($CaCO_3$), quartz (SiO_2) and malachite ($Cu_2CO_3.(OH)_2$).

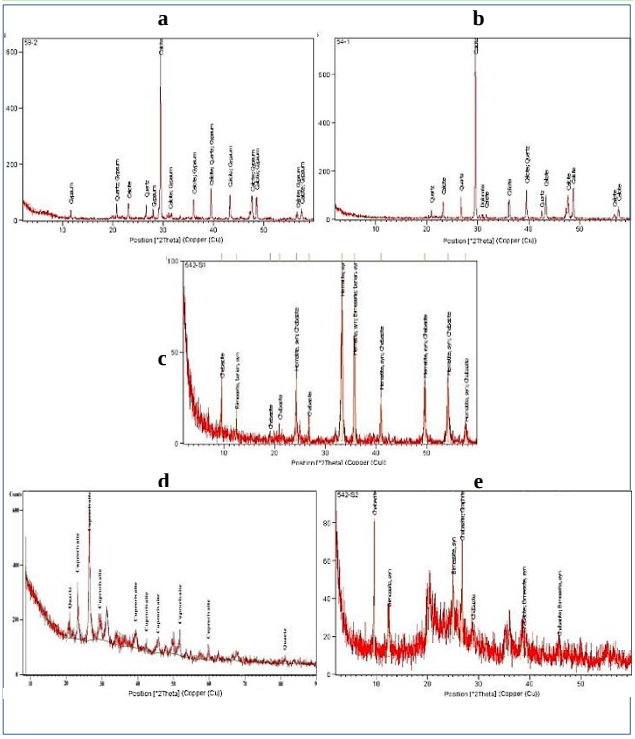

Figure (7) XRD patterns of the polychrome coffin components; **a.** ground layer, **b.** white, **c.** red, **d.** green, **e.** black pigments.

4.4. *SEM results of wooden coffin fibers*

SEM study revealed the severe weakness and deterioration of the wooden coffin due to a biological attack from insect and microbiological (fungal-bacterial) sources, fig. (8-a & b) [20]. shows the severe weakening of the wood due to gaps in the wood fibers and the erosion of the wood fibers caused by insect attack. In addition, the wooden containers were emptied from the inside due to fluctuations in temperature and humidity levels in the burial environment close to the surface of the earth, which caused mechanical disturbance of the coffin wood and indirectly exposed the coffin to the external environment, fig. (8-c). The presence of salt from sodium chloride, which is a product of using salt in the mummification process inside the wooden coffin, was also noted, fig. (8-d). The analysis of red sample using Energy Dispersive X-ray Analysis (EDX) revealed the presence of iron, attributing the red color observed in the sample. Additionally, traces of certain components from the surrounding environment were detected within the red coloration, fig. (8-e).

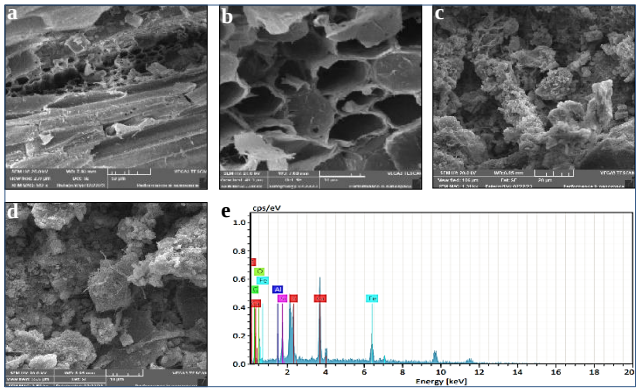

Figure (8) SEM photomicrographs of **a.** & **b.** wood fiber deterioration in fibers coffin woods, show detached fibers and degraded pit membranes, **c.** & **d.** collapsed wooden fiber vessels due to cracks and gaps, **e.** EDX chart of the red color sample

5. Discussion

Microscopic investigation revealed that the coffin and lid were crafted from sycamore wood, a locally available material commonly employed in 21st dynasty coffin production [16]. Arabic gum was identified as the binding agent used in conjunction with the colored materials for inscriptions, writings, and decorations on both the lid and the coffin [17]. XRD analysis provided insights into the composition of the ground layer and various pigments, including calcite, gypsum, dolomite, hematite, malachite, and carbon, used for the white, red, green, and black pigments, respectively [18,19]. Unlike other wooden coffins found in the Tabba El-Geish excavation in Saqqara, which were interred directly in contact with the ground without protective layers, this particular coffin was housed within a stone room likely constructed with stones sourced from a nearby temple. This unique preservation environment contributed to the coffin's remarkable condition upon discovery. However, microscopic examination revealed evidence of biological deterioration resulting from high relative humidity, leading to the infestation of microorganisms and insects on both the wooden coffin [20] (primary infection) and the enclosed mummy (secondary infection). Consequently, sterilization of the coffin was imperative prior to commencing the treatment stages [21]. Scanning electron microscope examination highlighted the impact of temperature and relative humidity fluctuations on the coffin's structural integrity, causing mechanical stresses and weaknesses in the cellulose fibers that constitute the wood. To address the coffin's fragility and instability, a step-by-step treatment approach was adopted. The conservation process will commence with mechanical cleaning as the initial step, aimed at removing fine and loose particles of dust and sand [22,23]. Subsequently, a chemical cleaning method will be employed using a 1:1 mixture of ethyl alcohol and water, and the peels will be stabilized using Primal 10%. Following this,

the restorer will proceed with surface consolidation using 3-5% of Paraloid B72 diluted in trichlorethylene [24]. Japanese paper and Klucel-G (10%) will be utilized to safeguard the surface, ensuring the preservation of colors and paintings [25]. Subsequently, the careful lifting of the mummy from the coffin will mark the initiation of the next stage [26]. This will enable internal cleaning and sterilization using Cydial 3%. To strengthen cracks and gaps, a braided cotton rope saturated with 25% concentrated Paraloid B72 will be incorporated. Precise conserve of missing parts of the wood will be accomplished using balsa wood [27]. For strengthening purposes, Paraloid B72 will be employed at concentrations ranging from 5% to 12%. The gaps in the coffin base will be filled using a mixture of micro-balloons and cotton fibers, enhancing the physical properties [28]. Microcracks and gaps will be chemically bonded using micro-balloons and a 15% solution of Paraloid dissolved in acetone as an adhesive. To ensure a seamless appearance, color retouching will be conducted, matching the color of the surrounding coffin wood [29]. Consistent color matching will be maintained throughout the merging stages [30]. In the final stage of conservation process, the paint layer and the coffin mask will be reattached after undergoing various treatments.

6. Treatment of the Polychrome Wooden Coffin.

Based on previous examination and analysis studies conducted on the discovered polychrome wooden coffin in the excavations of the MISR University at Saqqara, it has become necessary to urgently carry out conservation operations to preserve the coffin, the conservation process should be conducted systematically and meticulously to ensure the preservation of the wooden coffin with wooden lid and the safety of the restorer performing the conservation procedures, the conservation procedures were performed at the wood laboratory in the conservation Center in Saqqara.

6.1. *Sterilization the wooden coffin and its wooden lid*

Prior to any conservation operations on the lid and wooden coffin, sterilization procedures were conducted using paradox (Para-Di Chloro benzene) dissolved in acetone at a concentration of 3% for a period of 21 days. This process was carried out to eliminate any potential biological or microbiological growth, fig. (9) [21].

Figure (9) sterilization process before starting the stages of treatment and conservation of the polychrome wooden coffin in the wood conservation laboratory.

6.2. *Mechanical cleaning*

The cleaning process involved removing dirt, dust, stains, biological residues, and layers of calcified salt from the surface of the lid and coffin. Due to the fragile state of the coffin cover and colored coffin, the cleaning process was carefully carried out using soft brushes to ensure that no mechanical damage was caused to the cover or coffin. All dirt and debris were successfully removed without any damage to the lid or coffin, fig. (10) [22].

Figure (10) mechanical cleaning of the wooden coffin, using types of brushes and simple tools usually use in cleaning treatment.

6.3. *Removal of salt*

The wooden coffin contains the remains of a mummy from the Late Period. One of the characteristics of the mummification technique during this era is that it resulted in a relatively weak state of the mummy. Additionally, the coffin's direct contact with the soil, efflorescence salt appeared on the surface of the lower face and sides of the coffin. In order to prevent any further damage to the coffin, it was necessary to mechanically remove the salts [23].

6.4. *Chemical cleaning*

In cases where dirt, stains, and biological residues could not be removed via mechanical cleaning, various organic solvents and solvent combinations were used. A mixture of Acetone, Methanol, and Ammonia solution was found to be effective in removing excreta and residue accumulation from insects and birds [24].

6.5. *Facing (surface protection)*

After studying and examining the wooden coffin upon its removal from the site and transfer to the conservation lab for conservation, sterilization and mechanical and chemical cleaning processes were carried out. The first step in the conservation process was to isolate the inscriptions and colored scenes on the coffin lid and coffin to preserve them from any potential deterioration during subsequent conservation processes. This was achieved by cutting Japanese tissue paper into 5x5 cm squares and using Klucel G (hydroxyl propyl cellulose) in (IMS) with a concentration of 10%, fig. (11) [25].

Figure (11) isolated the inscriptions and colored scenes on the coffin lid and coffin, in order to preserve from damage during the subsequent conservation processes, by using Klucel G (hydroxyl propyl cellulose).

6.6. *Levitating of mummy remains*

Due to the difficulty of restoring the wooden coffin while it was closed, it was necessary to open it. The mummy remains

were then removed using 30×100 cm linen wraps, which were carefully passed under the mummy before being lifted out in one piece. A suitable support was then prepared, consisting of a sponge stuffed into a support frame and topped with two layers of larger-sized linen. The mummy remains were placed on the new support and wrapped with linen for preservation until the completion of the conservation process, after which they could be replaced.

6.7. *Consolidation of the wooden coffin and its wooden lid*

6.7.1. Mechanical consolidation

Parts of the lid and coffin were missing, leading to weakness in their respective areas and increasing stress on those parts. In order to preserve the wooden structure of the coffin, it was necessary to mechanically intervene using balsa wood. The dimensions and sizes of the gaps were determined, and a piece of balsa wood was cut to the same dimensions and sizes before being placed in the gap and bonded with micro balloon and Paraloid. Paraloid was first applied to the edges of the gap, followed by the addition of balsa wood with both Paraloid and micro balloon. After drying, the balsa wood was painted in a color similar to the color of the coffin to preserve its archaeological value. Mechanical consolidation of the coffin using gap fillers such as micro balloon and cotton fibers was also carried out to address missing wood portions resulting from insect infestation in the lid and coffin process, fig. (12) [26,27].

Figure (12) **a.** assembling and joining processes between parts of the two sides of the disassembled coffin lid, **b.** use of balsa wood in completing the missing parts of the sides and lid of the wooden coffin, then coloring the balsa wood in a color similar to the original color of the coffin and lid

6.7.2. Chemical consolidation

The base of the wooden coffin had partially deteriorated due to insect attacks that affected the mummy and the coffin. To prevent further deterioration, chemical consolidation was carried out. The strengthening process involved the use of Paraloid B72 with a concentration ranging from 5% to 12%. Gaps were filled using micro balloon with the addition with cotton fibers for consolidation and to improve the physical properties of the wooden coffin base [28].

6.8. *Treatment of warping of wooden coffin panels*

The wooden coffin panels that suffered from buckling were placed on a flat surface and wetted with a solution of distilled water and ethyl alcohol at a concentration of (2:1). Appropriate loads were applied to the panels until they regained their original physical shape. DEGALAN (Plexisol) P 550-40 chemical support was added between each two of these panels, which were then connected to each other using plastic clamps from their edges. Japanese tissue paper was placed between the ends of the clamps and the wood of the panels to prevent any damage, fig. (13) [29].

Figure (13) final cleaning and treatment using Paraloid B72 at conc 5% to 12%, and the gaps were filled using a micro balloon with cotton fibers for consolidation.

6.9. *Assembling and final treatment of the coffin*

The separate coffin panels that suffered from severe weakness in the wooden structure of the lid and coffin were consolidated and assembled after warping of wooden coffin panels and consolidating the deep cracks, micro cracks, and missing micro parts in the coffin. The separate parts of the lid and coffin were assembled by making wooden tenons with the same dimensions and sizes as the missing old parts of the coffin. Paraloid B72 with a ratio of 45% was used as an adhesive [30]. Fine longitudinal and transverse gaps and cracks were strengthened and assembled using 30% Paraloid and sawdust as a filler. Missing and separated parts of the coffin were also assembled. Fine cracks and gaps were chemically consolidated using a micro balloon with 15% Paraloid dissolved in acetone as an adhesive. A color similar to the color of the adjacent part of the coffin wood was added to the adhesive paste to ensure that it matched the surrounding area. This was applied in all stages of the coffin after gaping filling, fig. (14) [31].

Figure (14) final treatment steps of the coffin

7. Conclusion

This paper discusses the coffin that was discovered at Saqqara, which is dated back to the 21st dynasty. It belonged to a wealthy lady "Irwt", evident from the burial process. She was buried in a room constructed of reused limestone containing a wooden coffin with a wooden lid., with high-quality linen layers used to wrap the mummy. Lady "Irwt" was buried next to the temple of Hathor, indicating her importance in society. The wooden coffin, was placed inside a large wooden lid decorated with vertical-colored bands, have held religious texts and scenes. The wooden coffin was then buried inside a stone room made from reused stone blocks. The coffin lists important titles and includes a prayer for Lady "Irwt" to be buried in the west, symbolizing

stability and eternity. Scientific examinations and analyses of the wooden coffin revealed significant deterioration, including detachment, cracks, fractures, and infestation by microorganisms and insects. Several scientific techniques such as LOM, FTIR, SEM EDAX, and XRD were utilized for analysis. The findings indicated that the coffin was constructed from sycamore wood and adorned with inscriptions in various colors: white (calcite), red (hematite), blue (azurite), and black (Graphite). The conservation process entailed sterilization, mechanical and wet cleaning, and chemical treatment using organic solvents for wood preservation.

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