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TUTANKHAMEN'S SMALL SHRINES (NAOSES): TECHNOLOGY OF WOODWORKING AND IDENTIFICATION OF WOOD SPECIES

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Abstract

The focus of this paper is to reveal unknown features and to obtain still more information on technology of wood working used on the black shrine-shaped boxes from Tutankhamen collection. Moreover, the authors were significantly interested in identification of the wood species and shed lit on the reflection of The sudden death of the young king, the value of wood and its relative scarcity, not only in ingenious shrines construction methods and the incorporation of many fragments of timber, but also in the presence numerous pieces that show clear evidence of reuse from earlier objects. Patching, even for the royal wood workings, with another piece of wood secured by dowels and white pastes was one option and knots holes were sometimes drilled out and filled with plugs. The botanical species of the wood samples were identified by observing the thin sections under an optical transmission light microscope; technology of wood working were examined by visible imaging and raking light along with 3D software. The results revealed that cedar of Lebanon (Cedrus libani) and sycamore fig (Ficus sycomorus) had been used for making the shrines' boards and sleds while tamarisk (Tamarix sp.), Turkey oak (Quercus cerris L.), and Sidder (nabk) (Zizyphus spina Christi) used for making wooden dowels. Wooden pegs used to collect the shrine boards, roof and cornice together while the wooden joint of through mortise and tenon was used to collect the body of the shrine to the sled. The raking light was effective in revealing the tools marks.

***Keywords**: Tutankhamen; Wood identification; Cedrus libani; Ficus sycomorus; Raking light; Patching.*

Introduction

The shrine or naos (Greek term) could be either the inner chamber itself, or a rectangular chest or box made from wood or stone placed inside the inner chamber of the temple (The sanctuary). It contained a cult-image or a sacred statue of a deity. Often, an offering table was erected in front of the naos.

The sanctuary was the most special and important part of the temple. It was a very dark and mysterious place. Only the high priests and the pharaoh could ever enter the sanctuary.

In the middle of the sanctuary stood the shrine where the statue of the god or goddess was kept. The ancient Egyptians believed that sometimes during rituals the god or goddess would enter the statue. The naos as a small shrine is known in its typically Egyptian form since the beginning of Ancient Egyptian history. It eventually came to be represented as an Egyptian Hieroglyphs [1-6].

Some of the oldest examples are from the labels of the early pharaohs. Pharaoh *Narmer* is shown on the *Narmer* Mace head seated in a naos.

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Naos could also appear in representations, like a crown for a deity, or being held in the hands of statues of humans. Naos – bearing statues are called "*naophorous*" such as the statue of the *Ramesside* overseer of the treasury *Panehsy*. The earliest examples of such statues date to the 18th dynasty. The naos could also be used in connection with death, containing a funerary statue or a mummified animal [1-5].

Historical Background

Tutankhamen was an Egyptian pharaoh of the 18th dynasty (ruled c. 11332-1323 BC in the conventional chronology), during the period of Egyptian history known as the new kingdom or sometimes the new empire period. Tutankhamen tomb was discovered on November 1922 by Howard carter, the grave was relatively intact and crammed full of the most beautiful burial items and furniture.

Wood is the major raw material used for making the royal Funerary furniture of the king Tutankhamen; the ancient Egyptian artisans used wood for making different types of daily life and afterlife wooden objects founded in the tomb.

Many wooden species were used for making those shrines and the selection of the wooden material for a certain application was based on several criteria, such as: experience, material properties, and aesthetical requirements, also, equally important, wooden material availability which play an important role in ancient Egypt [7].

According to the complete records of the ten years excavation published by Griffith institute, oxford university, *Howard carter* mentioned in his dairy pocket of excavation about twenty three black shrine-shaped boxes on sleds founded in the tomb, sixteen shrines of them kept in the Luxor's storeroom since discovering till October 2016, recently those shrines have been transported to wood lab in the conservation center for conservation and preparing them for displaying in the Grand Egyptian Museum.

The authors in this study will shed light on those sixteen black shrine-shaped boxes on sleds founded in the antechamber and the treasury chamber. The shrines studied here are looks similar with little differences in dimensions, and structure.

Description

A tall narrow shrine of wood covered with a black resinous material, sloping roof with rounded front, folding doors fitting into sockets top and bottom. Wooden knobs, on each door for sealing (Fig. 3), although *Howard Carter* mentioned that there were remains of cord on one of those shrines but those remains are not found on the studied shrines.

Each of the sides made generally of one widths of board. Cornice in front made of a separate piece of wood; those shrines were used for keeping statues of ancient Egyptian deities and Tutankhamen's small statues [6, 7].

Materials and methods

Optical Microscopy

Thin sections of three principal anatomical direction of wood, transverse section (TS), longitudinal radial section (LRS), and longitudinal tangential section (LTS) at (30-50mμ) mounted on a slide glass by a mixture of acacia (Arabic gum), trichloro acetaldehyde monohydrate, glycerin (glycerol) and pure water for one day, a light microscopy Optika B-383PL equipped with digital camera 4083-B9, was used for identification of wood.

Visual assessment

Visual assessment, by the critical eye of the team work, was applied to determine the Techniques of manufacture used for making those shrines, and determining the wooden joints used for collecting the components of the shrine.

Documentation of techniques of manufacture by photography and 3D program

Techniques of manufacture, wooden joints and method of decorating were documented by using a high-resolution digital camera image (Sony Cyber-shot DSC-H300, 20.1mp, 35× Optical zoom) was used to create realistic photographic documentation and 3D Software programs for illustrating wooden joints used for collecting shrine's components.

Visible-induced infrared luminescence (VIL)

The setup required for the imaging technique included a D90 DSLR (CMOS sensor) digital camera modified to "full spectrum" fitted with A Nikon Nikkor 50mm f/1.8D AF lens. The camera was operated in fully manual mode and has been calibrated with the X-rite Color Checker Passport and its bundled software to create a camera profile for Adobe Camera Raw ®. The images were shot RAW and they were then color corrected using the camera profile above mentioned and white balanced.

For visible-induced infrared luminescence (VIL), a Schott RG840 cut-on filter and a light LED source were used as well as a mixture of radiation from LEDs and fluorescent lambs also used to see the fluorescence (luminescence) , while for visible (VIS) photography, A UV- and IR-blocking B + W 486 band pass filter and fluorescent radiation sources were used [8, 9].

(VIL) False Color image is made by digitally editing the VIS and VIL images. A copy of the VIS image is edited to become the VILFC image. The VIS green channel substitutes the blue channel and the red channel the green channel. Then, the VIL image constitutes the red channel of the edited VIS [10, 11].

Results and discussion

Wood Identification

Boards, roofs, Cornices, doors and Sleds

Identification of wood species used in making the boards and sleds of the shrines studied here proved that the cedar of Lebanon *Cedrus libani* (Fig. 5) was the most dominant wood species used for making the shrines' body and sleds while the sycamore fig *Ficus sycomorus* (Fig. 6) used frequently in shrines' body and sleds as found in shrines GEM-No's 21052, 21053, 21060, 21061, 21062, 21065 and 21070 as shown in tables 1 and 2, and extensively in the two big shrines GEM_No 21072 and 21073, as shown in table 3. Tamarisk, *Tamarix aphylla* were used in limited as identified in the right and left sides of the shrines' sleds GEM_No 21046 and 21055 (Table 4) [12-23].

Table 1. Anatomical features used for the identifications of taxa.

Taxa	Transverse section	Radial section	Tangential section
Cedrus libani	Early to latewood transition mostly gradual. Resin duct only traumatic.	Scalloped tori in tracheid pits. Cross fields characterized by mostly taxodioid simple pits. Radial tracheids present. end walls of ray parenchyma cells distinctly pitted (nodular)	Rays rather high. Presence of radial resin duct in very large rays irregularly shaped.
Ficus sycomorus	Diffuse porous, growth rings indistinct. Vessel large and mostly solitary. Axial parenchyma in tangential large bands.	Perforation plates simple. Crystals in axial parenchyma.	Rays large, up to 14 cells wide, heterocellular.

Table 2. Wood Identification of fourteen similar shrines' body and sleds

No	GEM_ No.	Wood Identification						
		Doors	Right side	Left side	Back side	Roof	Cornice	Sled
1	20971	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*
2	21045	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*

3	21046	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*		*Cedrus libani*	*Tamarix aphylla*
4	21052	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Ficus sycomorus*		*Cedrus libani*	
5	21053	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Ficus sycomorus*		*Cedrus libani*	
6	21055	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*		*Cedrus libani*	*Tamarix aphylla*
7	21059	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*		*Cedrus libani*	
8	21060	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*		*Cedrus libani*	*Ficus sycomorus*
9	21061	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Ficus sycomorus*	*Ficus sycomorus*		*Cedrus libani*	
10	21062	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Ficus sycomorus*	*Ficus sycomorus*	*Cedrus libani*	*Cedrus libani*	
11	21063	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*		*Cedrus libani*	
12	21064	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*		*Cedrus libani*	
13	21065	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Ficus sycomorus*	*Cedrus libani*		*Cedrus libani*	*Ficus sycomorus*
14	21070	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*	*Cedrus libani*		*Cedrus libani*	*Ficus sycomorus*

Table 3. Wood Identification of two big shrines' body and sleds

No	GEM No.	Wood Identification									
		Doors	**Right side**		**Left side**		**Back side**	**Roof**	**Cornice**	**Sled**	
15	21072	*Cedrus libani*	*Cedrus libani*	*Ficus sycomorus*	*Cedrus libani*	*Ficus sycomorus*	*Ficus sycomorus*	*Ficus sycomorus*	*Cedrus libani*	*Cedrus libani*	*Ficus sycomorus*
16	21073	*Cedrus libani*	*Cedrus libani*	*Ficus sycomorus*	*Cedrus libani*	*Ficus sycomorus*	*Ficus sycomorus*	*Ficus sycomorus*	*Cedrus libani*	*Cedrus libani*	*Ficus sycomorus*

Table 4. Anatomical features used for the identifications of taxa

Taxa	Transverse section	Radial section	Tangential section
Tamarix aphylla.	Semi-ring-porous to diffuse, vessels solitary and in small clusters and Axial parenchyma present in vasicentric or confluent distribution;	heterocellular rays with procumbent, square and upright cells mixed throughout the ray; simple perforation plates and lnter vessel pits alternate.	showing multiseriate rays commonly 5–20 cells in width
Ziziphus spina-christ	Semi-ring to diffuse-porous, vessels solitary or in radial multiples and axial parenchyma diffuse and scanty paratracheal.	rays with procumbent, square and upright cells mixed throughout the ray.	Rays unseriate; Details of tangential section(TLS) showing simple perforation plates; lnter vessel pits alternate.
***Quercus cerris* L.**	Ring-porous, Vessels in diagonal and radial pattern, predominantly solitary - Axial parenchyma diffuse in aggregate and Apotracheal parenchyma in narrow bands or lines up to three cells wide.	All ray cells procumbent, simple perforation plates and lnter vessel pits alternate.	Rays of two distinct sizes. Larger rays commonly more than I0 seriate and Aggregate rays present.

The skilled use of local and imported woods by carpenters and specialist woodworkers can be seen in a wide range of funerary objects. Scientific identification of wood species used has revealed that, in many instances, particular woods were intentionally selected for their properties, reuse of good quality timbers may not simply have been a cost-cutting stratagem; it may equally have reflected the desire to prevent good timber going to waste because its properties were well recognized and cherished. There may also have been spiritual or cultural reasons for perpetuating the use and reuse of specific type of wood [15-18].

Cedar of Lebanon (*Cedrus libani*) is imported from Lebanon and employed in Egypt for making sarcophagi, coffins and other appurtenances of burial, such as shrines, from as early as the 4th dynasty period to as late as the Ptolemaic period. The Eighteenth-dynasty shrines of which specimens of the wood have been examined are those that enclosed the stone sarcophagus (containing the nest of three coffins with the mummy) of Tutankhamen. The wood is pinkish–brown, straight grained, aromatic, very durable and taking a good polish [19].

The sycamore fig (*Ficus sycomorus*), a large, evergreen tree reaching a height of twenty meters, grows throughout Egypt. It is the only Egyptian tree of significant size and is modest in its requirements as concerns soil and water. The ancient Egyptians of expressed their affection and appreciation for the sycamore in many ways. It was held sacred to various deities; the sycamore was closely associated with Isis and with *Hathor*, who was called *Lady of the Sycamore*. Either the wood or the fruit of the sycamore fig has been found in graves as early as the predynastic period [20, 21].

Much use was made of the local trees (*Ficus sycomorus*, sycamore fig), particularly for large or long coffin planks, it was also popular for making the small wooden models often found in Egyptian tomb such as granaries, bakeries and boats. Although fig wood is of medium quality, it is light and easy to carve; it is susceptible to insect attack [15].

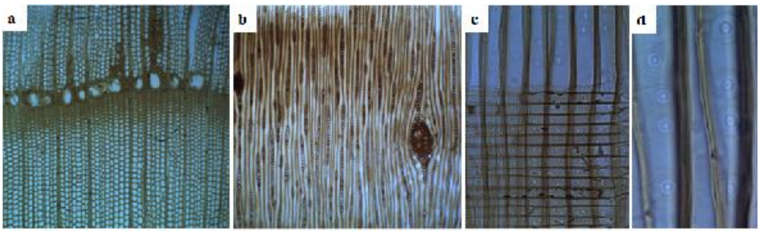

Fig. 1. The anatomical characteristics of *Cedrus libani* by OM in transmitted light: **a** - Transverse section (TS); **b** - Tangential section (TLS); **c** - radial section(RLS); **d** - Details of radial section showing scalloped torus margins of bordered pits present in the radial walls of tracheids which are diagnostic of *Cedrus libani.*

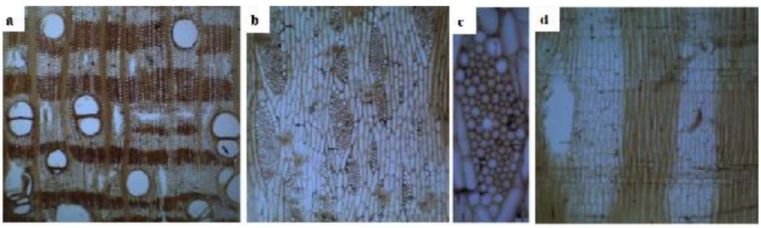

Fig. 2. The anatomical characteristics of *Ficus sycomorus* by OM in transmitted light: **a** - Transverse section (TS); **b** - Tangential section (TLS); **c** - laticifers were observed in rays (arrow head); **d** - Radial section (RLS).

Wooden dowels

The wooden dowels were identified in Shrines GEM_No 21059 and 21072 as Tamarisk (*Tamarix. sp*) (Fig. 3), sidder (*Ziziphus spina-christi*) in shrine GEM_No 21046 (Fig. 4) and Turkey oak (*Quercus cerris* L.) (Fig. 5) in shrines GEM_No 21045, 21053, 21059 and 21062 [12, 24].

Pieces of Tamarisk (*Tamarix. sp*) had been used in limited in the sled of some shrines such as shrines GEM_No 21046 and 21055.

When constructing wooden artifacts in ancient Egypt, usually, in contrast to the plank wood, carpenters often choose different types of woods for the interconnecting elements, such as the dowels and tenons. By choosing woods that are denser, such as the local acacias, sidder (*Ziziphus spina-christi*) and tamarisks. Tight joins and connection could be made between blanks or between added sections. Tamarisk and sidder are unlikely to have been available for use as large planks; their wood is often twisted or knotty. However, both are ideal where short lengths of timber are required, for precisely fitted dowels and tenons which are integral to the stability and coherence of construction, and for small objects [15].

Tamarisk (*Tamarix aphylla*) indigenous tree, ever green up to fifteen meters high, the tamarisk is occasionally mentioned in ancient texts from the old kingdom onwards, Herodotus states that certain rafts used in connection with boats were tamarisk, wood is dense and coarse [19]. The Egyptian carpenter realized that and used this wood for making wooden pins, tamarisk, too, could be used for tenons and dowels in internal construction of coffins [15]. In the Old Kingdom texts, the sacred roles of the plants are described and established. Tamarisk was represented the god Osiris [25, 26].

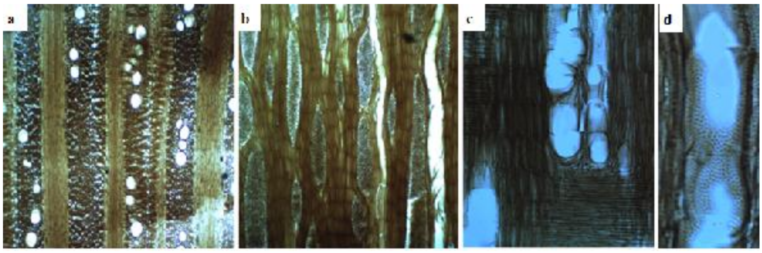

Fig. 3. The anatomical characteristics of *Tamarix aphylla* by OM in transmitted light: **a.** Transverse section (TS); **b.** Tangential section(TLS); **c.** Radial section (RLS); **d.** detail of Radial section (RLS) showing simple perforation plates and inter vessel pits alternate

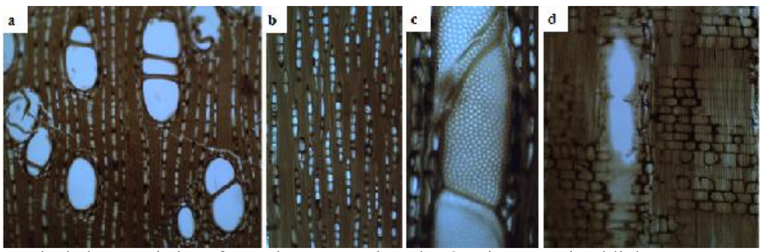

Fig. 4. The anatomical characteristics of *Ziziphus spina-christ* by OM in transmitted light: **a.** Transverse section (TS); **b.** Tangential section (TLS); **c.** Details of Tangential section (TLS) showing simple perforation plates; lnter vessel pits alternate; **d.** Radial section (RLS)

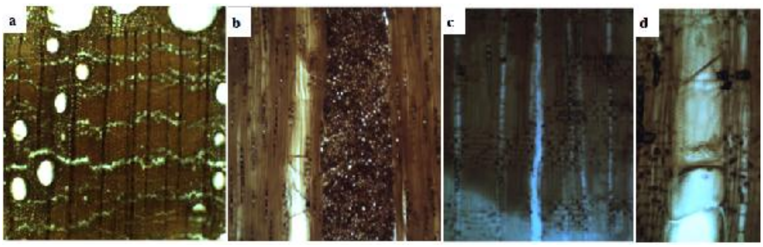

Fig. 5. The anatomical characteristics of *Quercus cerris* L. by OM in transmitted light: **a.** Transverse section(TS); **b.** Tangential section(TLS); **c.** Radial section (RLS) showing All ray cells procumbent **d.** Details of Radial section (RLS) showing simple perforation plates and lnter vessel pits alternate

Sidder (nabk), *Zizyphus spina Christi* another indigenous tree, this tree is not large enough to provide the boards that formed the main parts of the shrines, but its wood is hard and durable and sufficiently enough for making dowels.

Turkey oak (*Quercus cerris* L.) the cork oak occurs in the western Mediterranean region. One of the dowels from the large gilt shrines enclosing the sarcophagus of Tutankhamen was identified as oak. The heart wood of oak is light tan or brown, hard, strong and durable but not such high grade wood as some other species [19].

Technology of Wood working

Preparation of timber

Numerous scenes in tomb paintings and meticulously detailed model discovered in the eleventh dynasty burial of *meketre* give us clues to the way of which wood workers approached their material. After a tree was felled and the side branches removed, the trunk was chopped into logs and taken to the carpenter's workshop. Long, solid pieces were prepared by chopping off the bark and sapwood to expose the structural wood from which wooden artifacts could be manufactured. Generally, wooden planks were prepared by strapping the trunk or log vertically to an upright post fixed into the workshop floor. The planks were then cut by sawing down the length of the trunk (known as through – and through or tangential sawing. These planks were seasoned (allowed to dry in the open air) to remove most of their moisture content, after which they were ready for use. In addition to the saw, essential tools employed by the woodworker were adzes, chisels and wooden mallets with which to strike them, try squares, awls for making holes, small engraving tools, and bow-drills. Surfaces were smoothed by rubbing them down with small blocks of sandstone.

Fig. 6. Images with marks on wood: Saw marks on a sled of shrine GEM-No 21073: **a -** Flat light; **b -** Racking light; Marks left by sanding tool inside face of a side board from shrine GEM-No 21062; **c** - Flat light; **d -** Racking light; **e** - Cone shape of dowel hole by bow_drill GEM-No 21046; **f** - Marks left by adze on the sled of shrine GEM-No 21061

All these processes and tools leave characteristic evidence. The grain patterns visible on different components of an object indicate the direction in which the wood was cut, and remnants of the sweeping marks of the saw may show up when the surface is viewed in raking light (Fig. 6a and b). Scratches of sanding tool can be seen on the inside face of the shrines (Fig. 6c and d) by raking light. The twisting bit of a bow-drill leaves a cone shape in the bottom of a dowel hole (Fig. 6e), and the chop marks left by an adze or chisel capture both the size of the blade and its direction of travel (Fig. 6f) [15, 27-29].

Reuse, repairs and preparing the surface for decoration

The value of wood and, in times of economic stress, its relative scarcity, besides, the sudden death of the young king were reflected not only in ingenious shrines construction methods and the incorporation of many fragments of timber, but also in the presence numerous pieces that show clear evidence of reuse from earlier objects. For example, some parts are riddled with redundant dowel holes, and the inside surface of the roof and cornice of shrine GEM_No 21072 (Fig. 7) are full of old mortises and remains of painted drawings indicate the reuse of these parts.

Fig. 7. Numerous of old mortises and remains of painted drawings in roof and cornice, shrine GEM_No 21072

Numerous methods of repair and making good were used to cope with these features and other structural issues, such as diseased or damaged timber that had to be removed, areas of potential weakness, such as knots, and the many gaps between ill-fitting sections of wood.

Patching with another piece of wood secured by dowels and white pastes as shown in shrine GEM_No 21061 (Fig. 8a) or secured only by white paste was one option [15], shrine GEM_No 21062 (Fig. 8b), knots holes were sometimes drilled out and filled with plugs, as seen in shrine GEM-No 21073 (Fig. 8c and d).

White pastes were used to fill gaps between panels and patching wood voids and seal joints in bared surfaces GEM-No 21070 (Fig. 8e). In some cases ancient Egyptian artisan used several methods such as patching securing with white paste and dowels and filling knot hole with wooden plug along together to repair one wooden board as shown in shrine GEM_No 21060 (Fig. 8f) [28].

Shrines' Construction

The visual investigation indicate that the ancient Egyptian carpenter used wooden dowels for collecting the shrine components (boards, Roof, Cornice and torus) together (Fig. 9), except the sled which connected to the widths boards of the shrine by tongues carved in those boards and mortises in the sled (Fig. 10). Folding doors fitting into sockets top and bottom may be made by using awl and chisel (Fig. 11a) the inside edges of the doors generally straight (Fig. 11b) but the other shrines, GEM_No's 20971, 21060, 21062, 21063 , were slopping (Fig. 12), although the resinous material was applied directly on the outside surface of shrines, the gaps between ill-fitting components of wood were filled with white paste to get a smooth and even surface for applying the black resinous material and secure the connection between those components and to secure through mortise and tenon joint (Fig. 13).

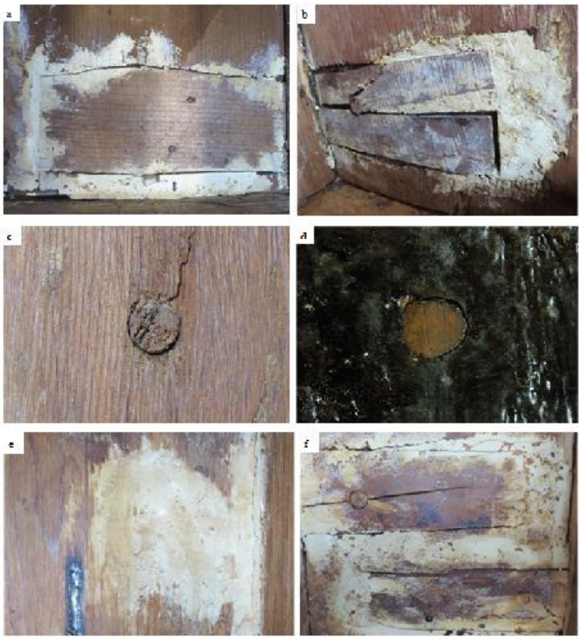

Fig. 8. Methods of repairing and patching wood. **a.** Patching with another piece of wood secured with dowels and white paste GEM-No 21061. **b.** Patching with another piece of wood secured with white paste GEM-No 21062. **c.** Knots holes filled with wooden plugs (inside face). **d.** Knots holes filled with wooden plugs (outside face). **e.** Filling gaps and wood voids by white pastes, shrine GEM-No 21070. **f.** Patching, wooden plug and securing with white paste in one wooden board, shrine GEM_No 21060.

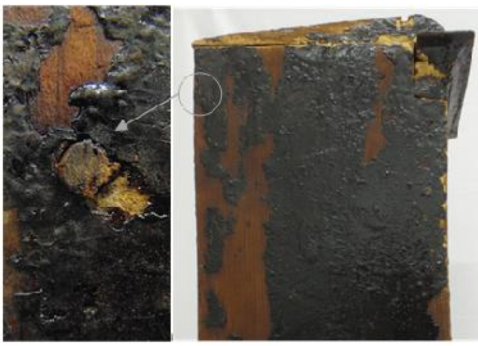

Fig. 9. Collecting small shrine boards, roof and cornice by wooden dowels (wooden pins)

Fig. 10. Collecting sleds with shrine panels by through mortise and tenon joint

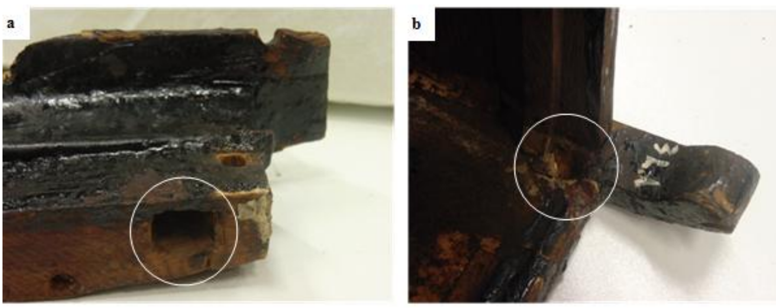

Fig. 11. Sockets of the folding door: a – up, b - bottom

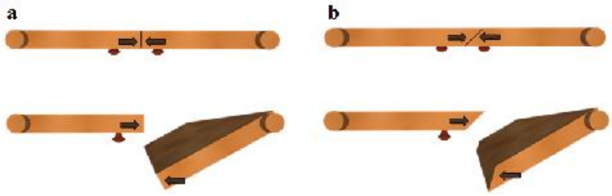

Fig. 12. Vertical view shows: a - the straight edges of the doors; b - the slopping edges of the doors

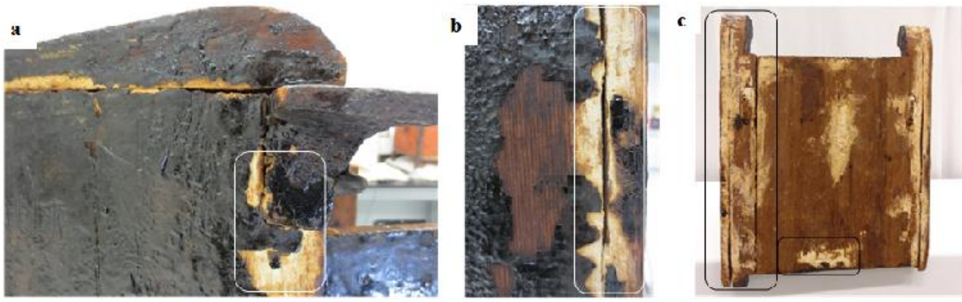

Fig. 13. Using white paste for filling gaps between shrine's components GEM_No 21045:
a. the cornice and the right board, b. the right and back boards, c. the sled.

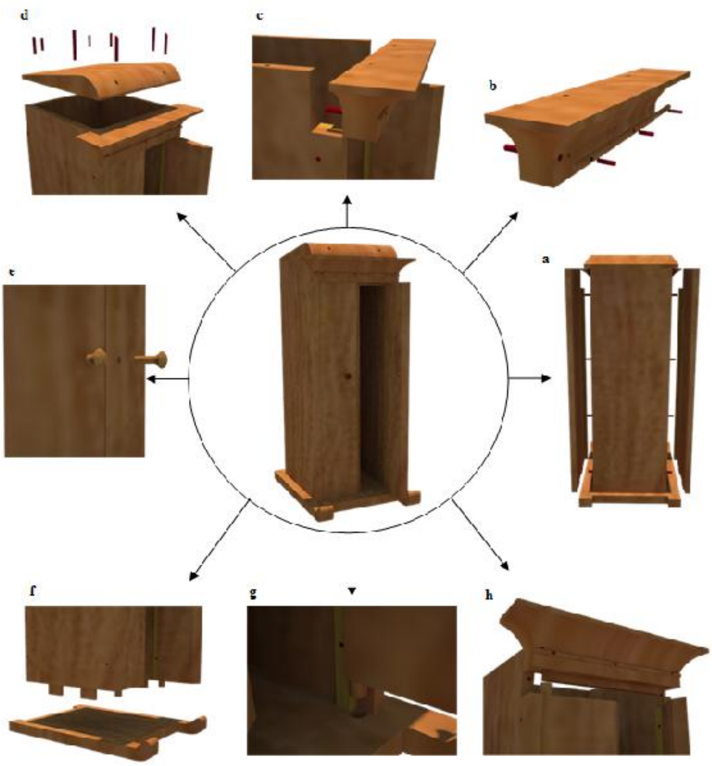

Fig. 14. Shrine Structure by 3D program. **a.** collecting shrines' boards by wooden dowels (Shrine's back). **b.** collecting torus with the cornice by wooden dowels. **c.** collecting cornice with the shrine boards by wooden dowels. **d.** collecting roof with the shrine body by wooden dowels. **e.** knobs are made of one piece fixed in the doors' holes. **f.** Collecting sled with shrine body by mortise and tenon joint. **g.** holes in sled and door axes. **h.** holes in cornice and door axes

Techniques of interconnecting

Structure of the shrine (Naos) and Techniques of interconnecting by wooden pegs and through mortise and tenon joint had been illustrated by 3D program in details. The shrines' components (boards, cornice and roof) are connected together by wooden dowels, while the sled connected to the shrine's body by through mortise and tenon joint (Fig. 14).

Visible-induced infrared luminescence (VIL)

Visible-induced infrared luminescence (VIL) has been developed at the British Museum and the Courtauld Institute of Art, London as a new imaging technique for the identification and characterization spatial distribution of Egyptian blue, that is one of the earliest synthetic pigments and was extensively used throughout the Mediterranean from the Fourth Dynasty in Egypt (*c.* 2500 B.C) until the end of the Roman period [10, 11, 30]. When this pigment excited in the blue, green or red range of the electromagnetic spectrum, it shows an intense and broad emission (full width at half peak height of c. 120nm) in the IR range, centered at about 950nm [31, 32]. This emission from Egyptian blue appears white or very pale areas in the VIL image, while all other materials appear black or grey [33-46]. In this case, VIL image indicated the presence of Egyptian blue pigment in the areas that appeared bright white (Fig. 15), while all other materials appear grey or black. VIL false color image showed that the areas painted with Egyptian blue appeared red.

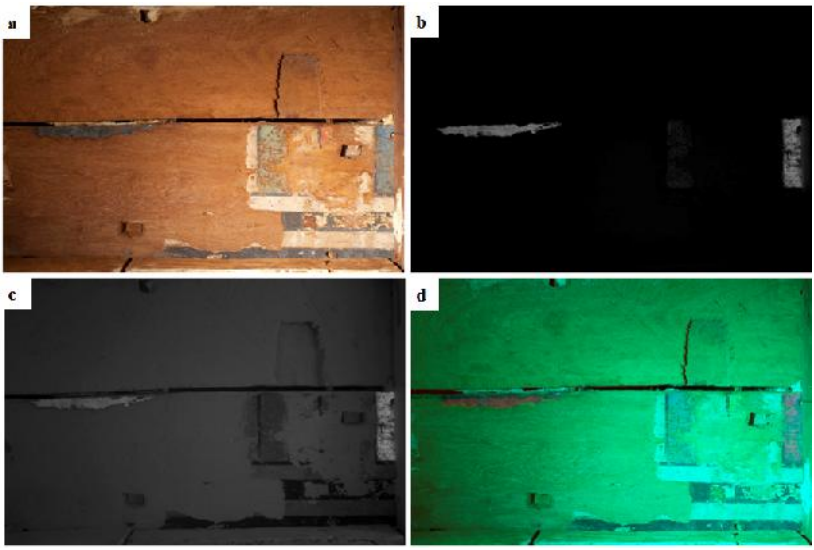

Fig. 15. The difference between VIS, VIL and VILFC images: **a.** visible (VIS) image; **b.** -induced luminescence image (VIL) with radiation from LEDs only showing Egyptian blue was used in the areas that appear bright white while all other materials appear black; **c.** -induced luminescence image (VIL) with a mixture of radiation from LEDs and fluorescent lambs showing Egyptian blue was used in the areas that appear bright white while all other materials appear grey; **d.** Visible-induced luminescence false color image showing the areas that appear red are where the Egyptian blue was applied.

Conclusions

The studied shrines (Naoses) of Tutankhamen are similar in structure and dimensions except two big shrines, GEM_No 21072 and 21073. Ancient Egyptian artisans used two wood species for making the shrines' body and three species for wooden dowels, choosing specific wood species for making boards and another species for dowels indicate that they aware of the properties of each species and used every type for particular purpose, cedar of Lebanon *Cedrus* *libani* and sycamore figure *Ficus sycamorus* are light and easy to carve, used for making main elements of the shrines (roof, boards, cornice, doors and sled), sidder (nabk) *Zizyphus spina Christi*, tamarisk *Tamarix aphylla* and Turkey oak *Quercus cerris* are more denser and durable used for interconnecting elements (wooden pegs).

The main wood species used for making the shrines (naoses) is cedar of Lebanon *Cedrus libani* while sycamore fig *Ficus sycamores* was used frequently and for expanding the two big shrines.

The sudden death of the young king, the value of wood and its relative scarcity were reflected not only in ingenious shrines construction methods and the incorporation of many fragments of timber, but also in the presence numerous pieces that show clear evidence of reuse from earlier objects. Patching, even for the royal wood workings, with another piece of wood secured by dowels and white pastes was one option and knots holes were sometimes drilled out and filled with plugs.

Marks of tools indicate that several tools (e.g. Saw, Adze, Bow drill, chisels, smoothing stone …etc.) were used for making the shrines. Wood voids, ill-fitting sections of wood filled with white paste to get smooth and even surface for applying the black resinous material.

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