The Cheops Boat – 50 Years Later

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Abstract:

In the last few years wood identification and specimen documentation have helped wood conservators and restorers choose appropriate treatment techniques. 50 years ago when the 1st Cheops boat was excavated specimen documentation was not as advanced as it is now. The reports that were considered of important value then are not sufficient to determine whether or not the ancient wood may resist the modern museum environment. By comparing old and new data, surprising results were obtained; for example not one report ever mentioned microbiological decay, whereas modern micrographs of samples that had been well preserved during the last five decades reveal the presence of an old infestation. Most of the literature published on the Cheops boat in the past, either depends on data obtained from the Chief Restorer Hag Ahmed Youssof or a report published in the year 1960. This paper deals with the specimen identification and documentation of this boat from a different perspective.

Keywords: Cheops boat, wood, specimens, deterioration

Italian Abstract:

Nei ultimi anni l’identificazioni del legnio e il modello di documentazione hanno aiutato I conservatori e i restauratori di scegliere l’ appropria technique del trattamento. 50 anni fa quando la 1a barca di Cheops stata scavata, il modello di documentazione non era avanzato come oggi. Questi rapporti che sono consederati di importanti valore non sono sufficiente per determinata certezza che l’antico legnio resiste l’ambiente del museo moderno per confrontare I vecchi e I nuovi dati si trovano sorprese nei risultati ottenuti. Peresempio non è stato mai un rapporto menzionato di danni microbiloig. Benche le micrografiche moderne dei cambiamenti che sono stati preservati l’ultimo cinque decenni hanno dimostrata la presenza di vecchio infetto. La maggior parte della letteratura pubblicata nel passato sulla barca di Cheops depende dei dati ottenuti dal capo di restauro Hag Ahmed Youssof o dei rapporti pubblicati nel 1960. Questo studio con l’identificazione e I documentazione di questa barca con differente prospettiva.

Parole chiave: barca di Cheops, legnio, modelli, deterioramento.

Introduction:

In 1954 people interested in archaeology got the opportunity to peer through the 22nd block that covered the Cheops (known as Khufu in some references) boat-pit. Through that hole they could not only see, but also smell fresh cedar wood. During the academic year ‘93/’94, late Prof. Dr. Saleh Ahmed Saleh, Professor of Conservation at the Faculty of Archaeology, Cairo University, Egypt, mentioned how much he would like to work on the Cheops 2nd boat. Many years have passed since then, and his dream was remembered, when a pile of dusty brown crumbled wrapping paper was found in his sample collection. Underneath this crumbled paper an old cigar box with the remains of either an envelope or brown packing paper were found. After a closer examination inside the box, it was evident that the box contained wood samples belonging to the first Cheops boat. According to the information on the remains of brown paper, these specimens were scientific samples sent back to Dr. Zaki Iskander from the British Museum (fig.1). There was no trace of any stamps, so it is not clear when the samples had been sent back to Egypt.
The box was full of small pieces of wood wrapped separately in white paper and brittle rubber bands. Every piece of paper had some important information on it, and this was the starting point of this paper.

Figure 1: The Cigar Box with the piece of wrapping paper

By referring to Jenkins (1980), it is possible to confirm that “Dr. Iskander had carefully removed a scrap of wood from the top of the pit and carried it himself to the British Museum’s chemistry laboratories, where it was identified as cedar.” It is interesting to note that Lipke (1984) refers to Jenkins’ assertion that the British Museum made positive identification of it being Cedrus libani. But he adds that the identity of the majority of the ship’s timbers has never been ascertained, and that it could not be confirmed as being cedar of Lebanon. Those who studied the boat seem to agree that most of the boat was made of Lebanese cedar, but it seems that they all referred to the data that was published in 1960, when Nour et al. first mentioned what Dr. E.W.J. Philips had reported after examining a few samples of wood parts of the boat microscopically in the Forest Products Research Laboratory, Princes, Risoborough, Aylesbury, Bucks, England. The results were as follows:

Sample A: A broken piece from the blade of the oar no. 22: “probably Ostrya species, presumably Ostrya carpinifolia, the hop hornbeam of south Eastern Europe and Asia Minor.”
Sample B: Piece from the board no. 47: “this seems to be a species of juniper (Juniper sp.)”
Sample C: Piece from the beam no. 14: “probably Balanites aegyptiaca, the lalob, soapberry or thorn tree.”
Sample D: Piece of the shaft of the oar no. 40: “Cedrus sp.; cedar of Lebanon or allied species”
Sample E: Wooden pegs from the door no. 23: “possibly an Acacia sp. identity very uncertain in this case.”
Sample F: Part of a tongue from the boat: “probably Mangifera indica.”

According to Nour et al. (1960) the kinds of wood of the first 5 samples were obtained from trees, which grew either in Egypt or in countries near to it such as Lebanon or Western Asia. The identification of sample F was a surprise, since it was known that Mangifera indica did not grow in Egypt anciently, and it is not probable that Egypt had commercial relations with India the home of this tree, at that very early time. Dr. Werner was asked to re-examine this sample but it seems the results of the re-examination were not published, if ever done. Presumably the identification of sample F is incorrect, because Archaeobotanists at the Cairo University Herbarium have not come across Mangifera indica while identifying wood samples dating back to ancient Egypt (Waly; 1994) and Gale et al. (2000) did not mention the presence of this wood in ancient Egypt.

Landström (1970) indicates that most of the wood was made of Lebanese cedar, but small details like the pegs in the planking were of sycamore and sidder. Lipke (1984) may have been more detailed in his information about the identification of the samples, because he wrote in detail about “the specific identification of five sample timbers that was undertaken by Dr. E.W.J Philips of the Forest Products Research laboratory, Bucks, England.” He included the same identification as Nour et al. (1960), excluding the 6th sample, because of identification doubts. Hag Ahmed
Youssof, chief restorer of the 1st Cheops boat went further in his interview with Lipke, on the basis of his familiarity with wood as a carpenter and his intimate knowledge of the ship’s timber; their feel, appearance, etc… “The tenons that align the planks are sidder, *Ziziphus spina-christi*. Sycamore, *Ficus sycomorus*, was used in small quantities for battens, pegs and other details. Acacia (probably *Acacia nilotica*) was used for cross bracing in some of the deck sections. All told that 95% of the ship is cedar from Lebanon. It is very hard, and even in the most infested parts of the Nile the worms (marine borers) will not eat it.”

Steffy (1998) mentions that “Most of the vessel was made from Lebanese cedar, although there are 467 tenons of sidder, as well as small quantities of hornbeam, juniper, sycamore, acacia and other North African and tropical woods.” Haldane (1993) reviewed the data related to the use of local and foreign wood used in the construction of ancient Egyptian “watercrafts”. It is surprising that micrographs of wood taken from 1st Cheops boat were not referred to. It is also strange that the wood decay was never published (if it was ever studied). Only Nilsson & Daniel (1990) mention that “occasional wetting of wood may lead to microbial attack that could be misidentified later as structural changes due to aging.” They were referring to the Cheops boat no.1. With the small treasure that Dr. Saleh left behind, it may be possible to assess the wood decay in Cheops boat no.1. Maybe that could be helpful when the time comes to bring the 2nd boat to light.

Materials and Methods:

6 specimens were chosen for studying wood samples taken from different parts of the boat. They were chosen for studies under light microscope or scanning electron microscope. Samples 1-5 were all studied using scanning electron microscope. Samples 3,4 and 6 were studied using a light microscope, but samples 1,2 and 5 were too fragile for light microscope preparation. Sections for light microscopy at 30-50 μm were stained using safranin and light green. Stained sections were dehydrated in alcohol-xylol series, cleared in clove oil and mounted in Canada Balsam. For scanning electron microscopy samples were prepared by fixing small pieces of wood in appropriate size on stubs with double-sided cellophane tape. Through sputter coating these samples were covered with gold and studied with a Joel-JSM-5400 LV SEM.

Table 1: Chosen samples for study, their actual location during burial in the pit and their identification according to LM and SEM

<table>
<thead>
<tr>
<th>Sample</th>
<th>Actual Location</th>
<th>Wood Identification</th>
</tr>
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<tbody>
<tr>
<td>1- Curved Beam D</td>
<td>Presumably found in the fourth layer.</td>
<td><em>Acacia sp.</em> (fig. 2-4)</td>
</tr>
<tr>
<td>2- Oar no. 40</td>
<td>Presumably found in the first layer.</td>
<td><em>Cedrus libani</em> (fig. 5-7)</td>
</tr>
<tr>
<td>3- Piece no. 250</td>
<td>Presumably found in the twelfth layer.</td>
<td><em>Cupressus sempervierens</em> (fig. 8-10)</td>
</tr>
<tr>
<td>4- Peg from no.1</td>
<td>Presumably found in the first layer.</td>
<td><em>Ziziphus spina-christi</em> (fig. 11-14)</td>
</tr>
<tr>
<td>5- Peg from no.2</td>
<td>Presumably found in the first layer.</td>
<td><em>Ziziphus spina-christi</em> (fig. 15-16)</td>
</tr>
<tr>
<td>6- Tenon from no.47</td>
<td>Presumably found in the second layer.</td>
<td><em>Ziziphus spina-christi</em> fig. (17-18)</td>
</tr>
</tbody>
</table>
Figure 2 & 3 Scanning electron micrograph of transverse and longitudinal surface of acacia wood sample taken from curved beam D showing slight microbial infestation in the vessel.

Figure 4 Scanning electron micrograph of conidia and hyphae on cell wall in acacia wood taken from curved beam D.

Figure 5 Scanning electron micrograph of transverse surface cedar wood taken from oar no. 40.

Figure 6 & 7 Scanning electron micrograph of longitudinal surface in cedar wood taken from oar no. 40 showing spores and rupturing of different cell walls.
Figure 8 & 9 Scanning electron micrograph of longitudinal surface of cypress wood taken from hull (piece no. 250)

Figure 10 Scanning electron micrograph of cypress wood taken from hull (piece no. 250) showing collapse of cell walls, presumably due to mechanical pressure

Figure 11 & 12 Scanning electron micrograph of longitudinal surface of sidder (peg no. 1) showing microbiological infestation and cell wall degradation in the middle lamella, primary wall and secondary wall.

Figure 13 & 14 Scanning electron micrograph of transverse surface of sidder wood (peg no. 1). Fungal spores are clearly seen in the vessels.
Figure 15 & 16 Scanning electron micrograph of sidder wood (peg no.2) showing dense mycelial growth around the vessel, and tyloses and spherical starch bodies produced in the vessel.

Figure 17 T.S. of sidder wood of sample taken from tenon no. 47. Growth rings distinct, vessels diffuse, solitary or in radial multiples of 2-3 in small clusters. Fissures clearly seen within the growth rings. (magnification 20x)

Figure 18 L.S. of sidder wood of sample taken from tenon no. 47. Rays 1-2 seriate weakly heterocellular, solitary crystals can be seen. Rupture in vessels evident (magnification 20x)
Specimen identification and documentation:

The identification of the 6 samples gave interesting results. The two pegs and the tenon were all made of sidder, *Ziziphus spina-christi*. This result agreed with what had been mentioned in previous references namely that a large number of pegs, tenons, etc… had been made of sidder. The fact that the beam D was made of acacia, *Acacia sp.* comes to confirm Hag Ahmed Youssef’s idea that this type of wood was used for cross bracing in some of the deck sections. The sample taken from oar no. 40 was identified as cedar, *Cedrus libani*, and that confirms Dr. Philip’s identification of the piece of the shaft of the oar no. 40. The surprising result was that the sample no. 250 taken from the hull was identified as cypress, *Cupressus sempervirens*. The use of this wood in the Cheops boat had not been mentioned in previous literature.

It is evident from the previous micrographs that the wood suffered from different problems. Most of the samples were too weak for light microscopy preparations, and would crumble under the fingers. SEM was a suitable option, and the micrographs obtained were sufficient for assessment of decay. It is clear that most of the wood suffered from microbiological infestation at some stage during the years of burial.

The collapse of the cell walls in some of the samples is due to the microbiological decay as in the case of the sidder sample taken from pegs no.1 & 2 (fig.11-16) and the cedar sample taken from the oar no. 40 (fig. 5-7). In the case of the cypress sample no. 250 (fig. 8-10), which was taken from the hull that was presumably in the 12th layer, the collapse of the cell walls is mainly due to the heavy loads of 11 wood layers that lay above it. According to Jenkins (1980) sample no. 250 was identified as weak and brittle wood that had cross shakes due to interaction with either the bedrock or the atmosphere. Wood decaying fungi are not the main cause of decay in that case. Certainly we cannot eliminate the fact that a very small amount of fungal mycelium was seen in the micrographs, but that was not the main reason for the deterioration of this sample.

It is clear that samples taken from the first layer, which was probably the least isolated area from exposure to air, showed a heavy fungal infestation, as in the samples from pegs no. 1 & 2 and the sample taken from the oar no. 40. Fungal infestation seems less in the oar sample, but an explanation for that is that the wood was identified as cedar (a conifer that should have an ability to retard decay, according to Tans et al., 1987). Ward (2000) concluding from Tans et al., mentions that the natural high concentration of fungicidal chemicals in the cedar wood slowed the decay rate throughout the burial years, now estimated at 200-1000 grams per year.

In the fourth layer fungal decay was evident in the acacia sample taken from beam D (fig.2-4), but this infestation was not dense and did not cause the same degree of degradation of the cell wall as in the case of peg no.1. In layer no. 12 fungal decay is minimal. That could be explained by the fact that either this sample was closer to the bedrock or that the wood is cypress (a coniferous wood) and at a distance from any source of airborne microorganisms.

There was no evidence of crystalline or non-crystalline salt in any of the micrographs taken from the six chosen samples, which means that there was no movement of salts or water containing salts within the wood during the years of burial. If any source of water had entered the pit, traces of salt should have been evident along some of the cell walls.

Discussion:

The humidity contents of wood samples taken from the 1st boat ranged from 9.0%-11%, with an average of 10% at the time of opening the boat pit. From Nour et al’s (1960) point of view that showed that the boat did not lose a great proportion of it’s original humidity content, since seasoned wood in Egypt contains about 10-12% of free water. The relative humidity inside the pit was 88% at 22°C (23rd Nov.1954). Outside the pit it was 44% relative humidity at 18°C. In June 1955 the relative humidity recorded inside was 80% at 25°C, while outside it was 64% relative humidity at 38°C. It was noted that the relative humidity inside the pit ranged between 75%-88%, while outside it ranged between 36%-64%. Temperatures inside the pit ranged between 19°C- 25°C, while outside it ranged between 17°C-38°C.
According to Jenkins (1980), some laboratories had questioned these figures, and a comparison was expected to happen with the opening of the 2\textsuperscript{nd} boat pit. These questions were answered some time later during a symposium held in Cairo, where the results’ measurements of the air composition of the 2\textsuperscript{nd} boat pit were reported. During sampling of air taken from the 2\textsuperscript{nd} pit no one could smell cedar, as had been mentioned in 1954, all that people could smell was “a slight hint of staleness”. It was obvious that there may be a direct leak to the outside from the 2\textsuperscript{nd} boat pit. Moreover, it seemed that the limestone used in the 2\textsuperscript{nd} pit was an important contributor to the total gas exchange, as a result of the diffusion process. According to Tans \textit{et. al.} (1987) all the gases found in the air outside the pit were found inside the boat chamber. In some cases the gas concentrations inside the pit were even higher than the outside air, but the temperature on 25\textsuperscript{th} Oct. 1987 was 27.5\(^\circ\)C (accuracy 0.3\(^\circ\)C) and the relative humidity 84\% (accuracy 2\%), which confirms that the measurements done in 1954-55 were accurate.

Fortunately after making a hole in block no.22 in May 1954, the state of the boat was predicted and it was advised not to open the hole frequently to avoid the drying up of the wood and consequently its deformation or disintegration. In November, when they started to take off the blocks, wooden boards covered with fire- and waterproof cloth, in order to minimize as far as possible the rate of the drying up of the wood, were used. During measurements at different intervals it was noticed that equilibrium was regained after about 10 hours from the time of closing the pit. The relative humidity would fall on opening the pit, and rise again on closing it. (Nour \textit{et. al.;} 1960)

Most of the timber that lay against the floor or walls of the pit exhibited soft areas and cross shakes, perhaps the result of some interaction between the atmosphere, the salt in the bedrock, and the cedar. We may summarize the extent of damage and theory of cause according to Lipke (1984) as follows:

Wood samples were either cracked, checked, crushed, fragmented, “spongy”, weak, brittle with some cross shakes, splits or warped. These problems mainly arose in wood found in layers 11-13. Rarely were they found in other layers. This damage was explained as a result of compression from weight of timbers above, interaction with bedrock and/or atmosphere or contact with lime stone support block.

It is surprising that not one reference mentioned the microbiological infestation of the wood, although the temperature and relative humidity recorded inside the pit in 1954-1955 should have been a suitable environment for the growth of microorganisms. But, if Dr. K. Lal Gauri’s theory is correct, then we may understand why the wood was not badly infested during its’ years of burial. Dr. Gauri suggested that the pit’s dew point was probably considerably lower than that of the ambient due to the hygroscopy of salts in the Giza bedrock and the depth of the pit. Probably the timber was subjected to temperatures constantly below 15.5\(^\circ\)C (60\(^\circ\)F), so that adequate moisture had condensed to keep the wood in a wet state throughout the period of its burial (Lipke; 1984). Even though the pit environment seemed to be suitable for the growth of microorganisms, the boat was almost intact and showed no signs of microbiological infestation. In literature dealing with the 1\textsuperscript{st} boat, there were no attempts shown of studying the microbiological decay of the wood. Tans \textit{et. al.} (1987) mention in their epilogue, referring to the 2\textsuperscript{nd} boat pit “Temperature and humidity seem favorable to biological decay, and there is absolutely no lack of oxygen. Cedar is one of the species of wood that has high natural concentrations of chemicals (e.g. fungicides) that retard decay.” It is true that coniferous woods are rich in resins, waxes and oils, and are therefore considered good repellents: but while studying a wooden coffin made of cypress wood, dating back to the Graeco-Roman period in Egypt, it was noted that the main cause of the decay was due to a fungal infestation (El Hadidi;1997). The astonishing result was that no air microflora was found inside the 2\textsuperscript{nd} boat pit. The data recorded in the work done by Ammar \textit{et. al.} (1987) indicated that under any incubation conditions there were no kinds of microbial groups. Tans \textit{et. al.} (1987) confirmed this, when they found that the atmospheric air of the pit was free of any dust particles, and although they had indicated that the pit was not very well sealed, yet there was no kind of dust turbulence inside the pit atmosphere. One explanation for the absence of
microflora could be that old materials are often brittle and excessively dry. Florian (2002) points out that “The dry brittleness is mainly due to the loss of the chemically bound water. The bonds that held water (referred to the strong covalent bonds that bond water to molecules) attach to each other and are no longer available for water binding – once bonded together they rarely become free again. The equilibrium moisture content EMC is reduced by loss of water bonding sites and may be protected from fungal infestation. This is preservation due to reduced EMC. (The EMC of wood in general at 20°C and 60% RH is a little less than 10% (ca. 9%), and just over 30% at 100% RH.)”. If we apply this information on the data obtained from the 1st boat, we may understand why the moisture content did not exceed 11%, although RH ranged between 75-88 % while the temperature ranged between 19°C- 25°C. The EMC of the wood must have been reduced during the years of burial.

Lipke (1984) tried to compare the condition of the Cheop’s boat timbers with that of the furniture in the Hetep-heres shaft which had been found several decades earlier in the pyramids area. The Hetep-heres furniture had completely decayed and was unrestorable. Lipke mentions that “it was noticeable that the boat pit’s floor is approximately 39.105m above the water table, whereas the Hetep-heres shaft’s floor is not more than 17.205m above the water table and sometimes perhaps as little as 3.9m.”

**Conclusion:**

There seem to have been many factors that played a major role in either preserving the Royal boat of Cheops or minimizing the decay of the timber. At the time of the discovery investigation techniques were much simpler and restoration criteria and standards were different from what we know now. Maybe the time has come to evaluate the state of the reconstructed Cheops I boat, which has been exposed to a modern museum environment for almost 25 years, after 25 prior years of mantling and dismantling of the whole boat (according to Hag Ahmed Youssof it was dismantled several times). It is very interesting to see micrographs of a splendid boat that is over 4500 years old and that was excavated 50 years ago. To any visitor the boat may seem to be in good shape, considering it’s age, but to the Chief restorer the rebuilding of the boat meant a lot of hard work, years of treatment and careful handling. Hag Ahmed Youssof mentioned in his report that during the first 25 years after the excavation many parts would deteriorate during treatment and exposure to different factors. That is easily explained now, because some of these parts had been either affected by microbiological attack or mechanical pressure during their years of burial. All that was needed for the deterioration was a suitable environment, and that is easily found in our modern world.

After 50 years of exposure to various factors, repair and treatments the state of the boat should be studied from a new perspective. Before any attempt is done to open the second pit, an assessment of wood deterioration should be attempted, because it is now obvious that the wood was not free of decay as it seemed at the time of excavation.

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