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King Khufu's Second Boat: Scientific Identification of Wood Species for Deckhouse, Canopy, and Forecastle

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Abstract: Very little published information is available on the scientific identification of wood species used in the construction of boats in ancient Egypt. This paper deals with the scientific identification of wood species used in the construction of the deckhouse, canopy, and forecastle of King Khufu's second wooden boat (4th Dynasty—Old Kingdom) in detail. This paper also discusses the principal technological characteristics of the identified woods, considering specifically their utilization for construction of the deckhouse, canopy, and forecastle. Almost all the woods used in the boat's deckhouse, canopy, and forecastle were made of two imported species of wood (*Cedrus libani A.Rich.* and *Juniperus* sp.), with two native species (*Ziziphus spina-christi* (L.) *Willd.* and *Vachellia* sp.) also identified. The analysis most surprisingly revealed the presence of *Ziziphus spina-christi* (L.) *Willd.* in 25% of the analyzed forecastle samples, which was discovered for the first time for making cross beams in the construction of boats in ancient Egypt. Another intriguing aspect of the boat's construction is the presence of *Juniperus* sp., which surprisingly showed that almost 85% of the analyzed samples were *Juniperus* sp., used in the deckhouse's boards, frames, and cross beams. The data let us examine the specific employment of the wood species used in the parts of the boat, which evidenced that the identified woods were suitably used for the construction of the different parts of the deckhouse, canopy, and forecastle of the boat.

Keywords: King Khufu; second boat; deckhouse; forecastle; wood identification; *Juniperus* sp.; *Cedrus libani A.Rich.*

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1. Introduction

The identification of wood species is one of the most important phases in the path of knowledge of a wooden artefact of historical–artistic interest, either for their conservation and restoration or for their cultural significance, highlighting the high capacity achieved by the ancient artisans in woodworking and the ancient trade route [1,2] The wood identification of ancient Egyptian artifacts has sparked a lot of interest in recent decades. Although many authors have carried out major reviews and studies of wood identification used on Egyptian artefacts, including coffins, shrines, headrests, statues, and portrait [2–5] from different periods in ancient Egypt, a few studies have been reported by some authors that are specific to wood identification of boats, in particular the first boat of King Khufu (4th Dynasty—Old Kingdom). For example, Nour, et. al. 1960 first mentioned the analysis by Dr. E.W.J. Philips of a few samples of wood parts of the first boat of King Khufu microscopically in the Forest Products Research Laboratory, Bucks, England, which showed the use of *Ostrya carpinifolia*, the hop hornbeam of South Eastern Europe and Asia Minor for a broken piece from the blade of the oar no. 22, a species of juniper (*Juniper* sp.) for a piece from the board no. 47, probably *Balanites aegyptiaca*, the lalob, soapberry or thorn tree for a piece from the beam no. 14, cedar of Lebanon (*Cedrus libani A.Rich.*) for a piece from the shaft of the oar no. 40, possibly an *Acacia* sp. for wooden pegs from the door no. 23, and probably *Mangifera indica* for a part of a tongue,

"identity very uncertain in this case [6] Landström (1970) indicated that most of the wood was made of Lebanese cedar, but small details, such as the pegs in the planking, were of sycamore and sid [7] 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 sixth sample, because of identification doubt [8] During her analysis of six wood samples taken from different parts of the first boat, El Hadidi, 2005, found the use of sidr, *Ziziphus spina-christi* (L.) *Willd.* for two pegs and a tenon; acacia, *Acacia* sp. for the curved beam D; cedar, *Cedrus libani A.Rich.* for a sample taken from oar no. 40, which confirmed Dr. Philip's identification of the piece from the shaft of oar no. 40; and cypress, *Cupressus sempervierens* for sample no. 250 taken from the hull, which had not been mentioned in previous literatur [9] In addition, Creasman, 2010 showed that the hull of the Dahshur boat of King Senwosret III (ca. 1874–1855 BC; Middle Kingdom) in the Carnegie Museum of Natural History, Pittsburgh, was completely built from *Cedrus libani A.Rich.*, with a few *Tamarix* sp. for tenons. He also showed that some hull planks from two additional Dahshur boats (Boat GC 4926 and Morgan Boat) that are on display in the Sharm El Sheikh Museum, were identified as *Cedrus libani A.Rich.* [10] Furthermore, in their first diagnostic study of 14 wooden samples from different parts of the second boat of King Khufu, to obtain as much information as possible on the botanical species of wood to provide necessary data for suitable conservation procedures, Zidan, et al., 2022 showed the use of *Cedrus libani A.Rich.* for two oars and cross beams; *Juniperus* sp. for two boards, frames, and cross beams of the deckhouse; and *Ziziphus spina-christi* (L.) *Willd.* and *Acacia* sp. for tenons and peg [11] Yoshimora, 2022 also mentioned the analysis of three samples of wood parts from the second boat of King Khufu in 2012–2013, which showed that the first sample was identified as *Vachellia* sp., the second as *Juniper* sp., and the third one as a *Cedrus libani A.Rich.* [12].

Despite the historical and archaeological significance of King Khufu's boats, only few published studies are available on the scientific identification of wood species used in the construction of King Khufu's boats, and these studies are far from comprehensive research. In addition, the identity of some woods is still doubtful. As a result, the purpose of this study is to conduct the first detailed scientific identification of wood species used in the construction of King Khufu's second boat (4th Dynasty—Old Kingdom) in order to implement the database concerning the utilization of different timber species used in the construction of the deckhouse, canopy, and forecastle of the second boat and to demonstrate the principal technological characteristics of the identified wood species.

2. Historical Background

In 1954, two boat pits were discovered south of the Great Pyramid of King Khufu (2589–2566 BCE) (Figure 1). Since the discovery of the two boats, the eastern boat has been conventionally called the "First Boat" and the western boat, the "Second Boat." Due to the bad condition of the wood, the second boat remained sealed in its pit until 2009, when a joint project between Egypt and Japan began, and the cover stones on the second boat pit were lifted for the first time after its closure during the reign of King Djedefra in the Old Kingdom of ancient Egypt (Figure 2). A comprehensive project aiming at the conservation and reconstruction of the second boat is now ongoing. In the scheme of this project, the identification of wood species was an important step in its scientific approach for the conservation and reconstruction of the second boat, so the first diagnostic study was focused on a preliminary study to obtain as much information as possible on the botanical species of wood to provide necessary data for suitable conservation procedure [11].

Figure 1. Location of Khufu's second boat site in the south side of the Great Pyramid, Giza, Egypt.

Figure 2. The second boat of King Khufu inside its pit.

In 2018, the authors started an analytical survey to characterize all the wooden parts of the second boat to contribute to improvements in technological knowledge regarding the construction of boats in ancient Egypt. In particular, to focus was on two main aspects: firstly, to implement the database concerning the utilization of different timber species in the boat; and secondly, to demonstrate the evolution of woodworking skills in the Old Kingdom and/or variation in the timber supply. The boat consists of different parts, including deckhouse, canopy, forecastle, deck beam, hull, rib, and oars. This current research focuses on the woods used for the construction of the deckhouse, canopy, and forecastle.

3. Materials and Methods

The procedures and methods of wood identification were performed on site, where a large number of wood samples were coded according to typologies and selected locations. In total, 200 wood samples were taken from different parts of the boat's deckhouse, canopy, and forecastle (only using small fragments that had fallen from the wooden parts that cannot be restored to the parts of the boat), as summarized in Tables 1–3.

3.1. Sample Preparation

Wooden samples were first examined under a polarizing digital microscope (USB, Dino-lite) at various magnifications to distinguish between hardwood and softwood. The softwood samples were immersed in primal CM330 15% (an acrylic-based thermo plastic emulsion resin, with low viscosity in aqueous dispersion) for 10 min before drying for a week in order to consolidate the wood tissues. The samples were then cut by hand with razor blades to obtain thin sections in the three anatomical planes (transverse, tangential longitudinal, and radial longitudinal), which were mounted on slides with a drop of Klucel G 3% (hydroxyl propyl cellulose) dissolved in ethanol and water (1:1) before being ready for microscopic identification at the same time.

Sectioning of fragile and brittle hardwood samples was nearly impossible, requiring an embedding treatment. As a result, an agar low-viscosity resin (LV) was used to maintain the sample integrity during cutting operations. The resin was made up of the following components: LV resin (4.8 g), VH1 hardener (2.6 g), VH2 hardener (2.6 g), and accelerator (0.25 mL).

Before wood embedding, the samples were first dehydrated three times with 100% ethanol, then three times with 100% acetone. For the embedding procedure, wood specimens were first soaked for 8 h in a 1:1 solution of LV embedding resin and acetone, followed by 8 h soak in a 2:1 solution of LV embedding resin and acetone. They were then placed in embedding molds or dry capsules filled with LV resin and polymerized in a 60° oven at for 24 h. After hardening, samples were cut with a sliding microtome to obtain thin sections, which were then stained with diluted 0.05% Toluidine blue on a hot plate for 20–30 s before being transferred to the slide with several drops of diluted solution of PARA mount-N.

3.2. Optical Microscopy (OM)

Carl Zeiss-Primo Star (Germany) microscope equipped with a TOUPCAM ™ digital camera (5.1 MP) in transmitted light was used to examine and observe the anatomical features of the three thin sections of each wood sample.

3.3. Species Identification

Observation and description of anatomical features for the wood samples were based on wood anatomy textbooks, databases, and atlase [13–18].

4. Results and Discussion

Four different taxa are identified: Juniper (*Juniperus* sp.), cedar of Lebanon (*Cedrus libani A.Rich.*), Christ's thorn or sidr (*Ziziphus spina-christi* (L.) *Willd.* L.), and acacia (*Vachellia* sp.). In Tables 1–3, the identified taxa are attributed to each different part of the deckhouse,

canopy, and forecastle. In addition, the anatomical features used to identify the wood species present are listed in Table 4.

For the deckhouse, the results surprisingly showed that almost 85% of the analyzed samples are from *Juniperus* sp., used in the boards, frames, and cross pieces of the deckhouse's sides, whereas 15% of the analyzed samples are from *Cedrus libani A.Rich.*, used in the cross beams and external cross pieces of the roof, as shown in Figure 3. Almost 100% of the analyzed samples are from *Cedrus libani A.Rich.*, which was used for the pillars, cross beams, and pillar bases of the canopy. As for the forecastle, almost 75% of the analyzed samples are from *Cedrus libani A.Rich.*, which was used for pillars and boards, whereas 25% of the analyzed samples are from *Ziziphus spina-christi* (L.) *Willd.*, which was used for the cross beams, as shown in Figure 4. Moreover, *Ziziphus spina-christi* (L.) *Willd.* and *Vachellia* sp. *(Acacia* sp.). were used for tenons and pegs. A database for the results of the comprehensive analysis on the wood identification of each piece of the boat was designed, so the results of the analysis can be archived systematically.

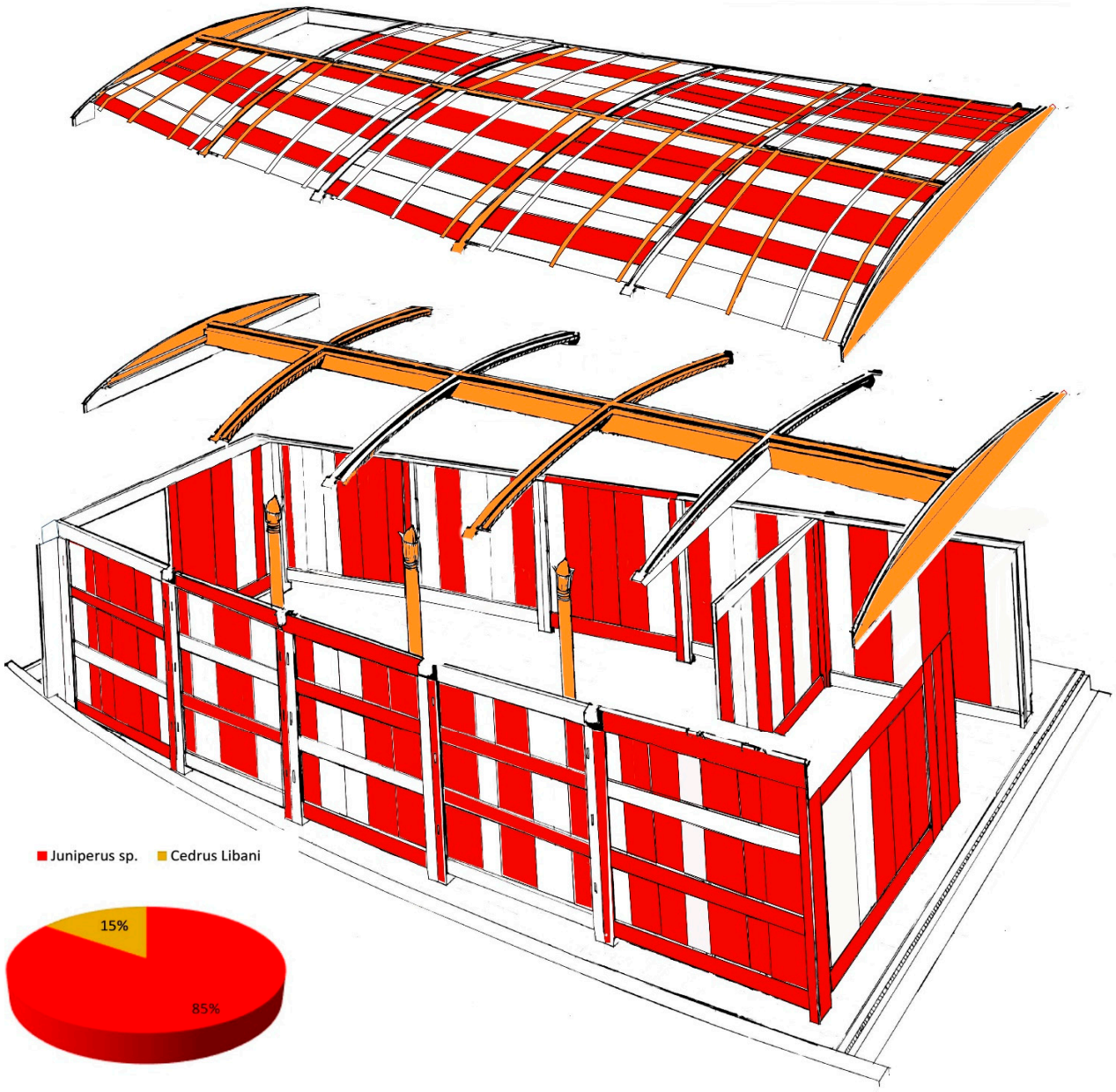

Figure 3. Rendering of the wood species used on the deckhouse as numbered in Table 1.

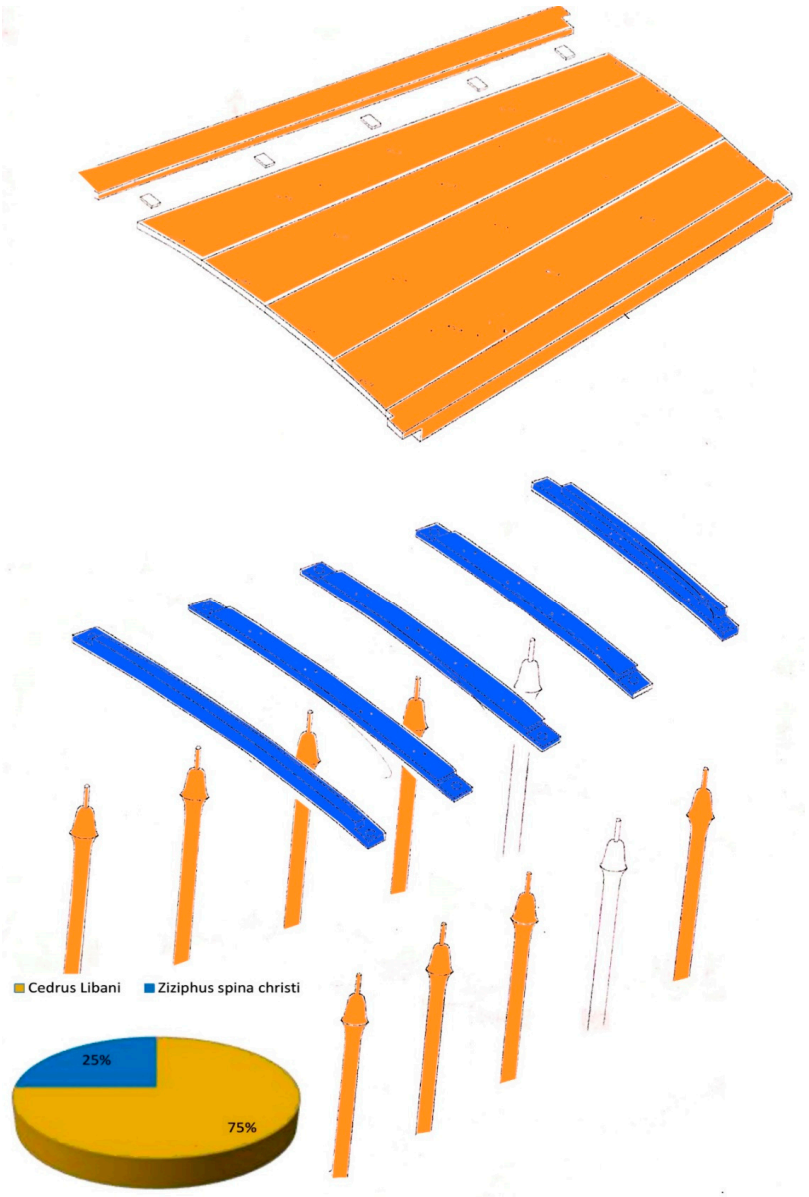

Figure 4. Rendering of the wood species used on the forecastle as numbered in Table 3.

Table 1. Sample number, piece name, excavation number, location, and species identification for the deckhouse elements.

Sample Number	Piece Name	Excavation Number	Location	Identification	
				English Name	Botanical Name
1	Frame	O0399	1-Star board wall (1st Panel)	Juniper	*Juniperus* sp.
2	Frame	O0400		Juniper	*Juniperus* sp.
3	Board	O0402		Juniper	*Juniperus* sp.
4	Board	O0403		Juniper	*Juniperus* sp.
5	Board	O0404		Juniper	*Juniperus* sp.
6	Board	00405		Juniper	*Juniperus* sp.
7	Board	O0407		Juniper	*Juniperus* sp.
8	Board	O0408		Juniper	*Juniperus* sp.
9	Cross piece	O0411		Juniper	*Juniperus* sp.
10	Board	O0522		Juniper	*Juniperus* sp.

Table 1. *Cont.*

Sample Number	Piece Name	Excavation Number	Location	Identification	
				English Name	Botanical Name
11	Frame	O0151	1-Star board wall (2nd Panel)	Juniper	*Juniperus* sp.
12	Cross piece	O0152		Juniper	*Juniperus* sp.
13	Cross piece	O0168		Juniper	*Juniperus* sp.
14	Board	O0170		Juniper	*Juniperus* sp.
15	Board	O0172		Juniper	*Juniperus* sp.
16	Board	O0174		Juniper	*Juniperus* sp.
17	Frame	O0564	1-Star board wall (3rd Panel)		
18	Frame	O0566		Juniper	*Juniperus* sp.
19	Frame	O0567		Juniper	*Juniperus* sp.
20	Cross piece	O0569		Juniper	*Juniperus* sp.
21	Board	O0570		Juniper	*Juniperus* sp.
22	Board	O0573		Juniper	*Juniperus* sp.
23	Board	O0574		Juniper	*Juniperus* sp.
24	Frame	O0459	1-Star board wall (4th Panel)	Juniper	*Juniperus* sp.
25	Cross piece	O0461		Juniper	*Juniperus* sp.
26	Frame	O0463		Juniper	*Juniperus* sp.
27	Board	O0464		Juniper	*Juniperus* sp.
28	Board	O0466		Juniper	*Juniperus* sp.
29	Frame	O0138	1-Star board wall (5th Panel)	Juniper	*Juniperus* sp.
30	Board	O0141		Juniper	*Juniperus* sp.
31	Board	O0142		Juniper	*Juniperus* sp.
32	Board	O0143		Juniper	*Juniperus* sp.
33	Board	O0144		Juniper	*Juniperus* sp.
34	Frame	O0146		Juniper	*Juniperus* sp.
35	Cross piece	O0148		Juniper	*Juniperus* sp.
36	Frame	O0252	1-Portside wall (1st Panel)	Juniper	*Juniperus* sp.
37	Cross piece	O0255		Juniper	*Juniperus* sp.
38	Frame	O0256		Juniper	*Juniperus* sp.
39	Board	O0258		Juniper	*Juniperus* sp.
40	Board	O0260		Juniper	*Juniperus* sp.
41	Board	O0261		Juniper	*Juniperus* sp.
42	Cross piece	O0352	2-Portside wall (2nd Panel)	Juniper	*Juniperus* sp.
43	Frame	O0353		Juniper	*Juniperus* sp.
44	Board	O0354		Juniper	*Juniperus* sp.
45	Board	O0358		Juniper	*Juniperus* sp.
46	Frame	O0553	2-Portside wall (3rd Panel)	Juniper	*Juniperus* sp.
47	Frame	O0555		Juniper	*Juniperus* sp.
48	Frame	O0556		Juniper	*Juniperus* sp.
49	Board	O0560		Juniper	*Juniperus* sp.
50	Board	O0561		Juniper	*Juniperus* sp.
51	Board	O0562		Juniper	*Juniperus* sp.
52	Cross piece	O0450	2-Portside wall (4th Panel)	Juniper	*Juniperus* sp.
53	Frame	O0452		Juniper	*Juniperus* sp.
54	Board	O0454		Juniper	*Juniperus* sp.
55	Board	O0457		Juniper	*Juniperus* sp.

Table 1. *Cont.*

Sample Number	Piece Name	Excavation Number	Location	Identification	
				English Name	Botanical Name
56	Frame	O0388	2-Portside wall (5th Panel)	Juniper	*Juniperus* sp.
57	Cross piece	O0389			
58	Board	O0394		Juniper	*Juniperus* sp.
59	Board	O0395		Juniper	*Juniperus* sp.
60	Board	O0396		Juniper	*Juniperus* sp.
61	Board	O0397		Juniper	*Juniperus* sp.
62	Cross piece	O0153	3-Stern side wall and doors (1st Panel)	Juniper	*Juniperus* sp.
63	Board	O0156		Juniper	*Juniperus* sp.
64	Board	O0157		Juniper	*Juniperus* sp.
65	Frame	O0163		Juniper	*Juniperus* sp.
66	Board	O0165		Juniper	*Juniperus* sp.
67	Board	O0166		Juniper	*Juniperus* sp.
68	Cross piece	O0305	3—Stern side wall and doors (2nd Panel)	Juniper	*Juniperus* sp.
69	Cross piece	O0307		Juniper	*Juniperus* sp.
70	Board	O0315		Juniper	*Juniperus* sp.
71	Board	O0316		Juniper	*Juniperus* sp.
72	Board	O0317		Juniper	*Juniperus* sp.
73	Cross piece	O0334	3—Stern side wall and doors (3rd Panel)	Juniper	*Juniperus* sp.
74	Board	O0345		Juniper	*Juniperus* sp.
75	Board	O0346		Juniper	*Juniperus* sp.
76	Board	O0347		Juniper	*Juniperus* sp.
77	Frame	O0360	4—Inner wall and doors (1st Panel)	Juniper	*Juniperus* sp.
78	Frame	O0361		Juniper	*Juniperus* sp.
79	Cross piece	O0362		Juniper	*Juniperus* sp.
80	Cross piece	O0363		Juniper	*Juniperus* sp.
81	Frame	O0364		Juniper	*Juniperus* sp.
82	Board	O0365		Juniper	*Juniperus* sp.
83	Board	O0366		Juniper	*Juniperus* sp.
84	Board	O0367		Juniper	*Juniperus* sp.
85	Board	O0368		Juniper	*Juniperus* sp.
86	Board	O0371		Juniper	*Juniperus* sp.
87	Board	O0176	4-Inner wall and doors (2nd Panel)	Juniper	*Juniperus* sp.
88	Board	O0177		Juniper	*Juniperus* sp.
89	Board	O0178		Juniper	*Juniperus* sp.
90	Board	O0179		Juniper	*Juniperus* sp.
91	Cross piece	O0181		Juniper	*Juniperus* sp.
92	Cross piece	O0184		Juniper	*Juniperus* sp.
93	Board	O0331	4—Inner wall and doors (3rd Panel)	Juniper	*Juniperus* sp.
94	Board	O0332		Juniper	*Juniperus* sp.
95	Cross beam	O0064	5—stern side wall and doors (1st Panel)	Juniper	*Juniperus* sp.
96	Frame	O0232		Juniper	*Juniperus* sp.
97	Board	O0234		Juniper	*Juniperus* sp.
98	Board	O0235		Juniper	*Juniperus* sp.
99	Frame	O0236		Juniper	*Juniperus* sp.
100	Frame	O0237		Juniper	*Juniperus* sp.

Table 1. *Cont.*

Sample Number	Piece Name	Excavation Number	Location	Identification	
				English Name	Botanical Name
100	Board	O0191	5—stern side wall and doors (2nd Panel)	Juniper	*Juniperus* sp.
101	Board	O0192		Juniper	*Juniperus* sp.
102	Cross piece	O0006	1—Roof (1st Panel)	Cedar of Lebanon	*Cedrus libani A.Rich.*
103	Cross piece	O0007		Cedar of Lebanon	*Cedrus libani A.Rich.*
104	Board	O0008		Juniper	*Juniperus* sp.
105	Cross piece	O0123		Cedar of Lebanon	*Cedrus libani A.Rich.*
106	Cross piece	O0124		Cedar of Lebanon	*Cedrus libani A.Rich.*
107	Board	O0125		Juniper	*Juniperus* sp.
108	Board	O0126		Juniper	*Juniperus* sp.
109	Board	O0127		Juniper	*Juniperus* sp.
110	Board	O0128		Juniper	*Juniperus* sp.
111	Board	O0129		Juniper	*Juniperus* sp.
112	Board	O0130		Juniper	*Juniperus* sp.
113	Cross piece	O0412	1—Roof (2nd Panel)	Cedar of Lebanon	*Cedrus libani A.Rich.*
114	Cross piece	O0413		Cedar of Lebanon	*Cedrus libani A.Rich.*
115	Cross piece	O0415		Cedar of Lebanon	*Cedrus libani A.Rich.*
116	Board	O0418		Juniper	*Juniperus* sp.
117	Board	O0420		Juniper	*Juniperus* sp.
118	Board	O0423		Juniper	*Juniperus* sp.
119	Cross piece	O0577	2—Roof (1st Panel)	Cedar of Lebanon	*Cedrus libani A.Rich.*
120	Board	O0579		Juniper	*Juniperus* sp.
121	Board	O0581		Juniper	*Juniperus* sp.
122	Board	O0582		Juniper	*Juniperus* sp.
123	Board	O0585		Juniper	*Juniperus* sp.
124	Cross piece	O0424	2—Roof (2nd Panel)	Cedar of Lebanon	*Cedrus libani A.Rich.*
125	Cross piece	O0425		Cedar of Lebanon	*Cedrus libani A.Rich.*
126	Board	O0428		Juniper	*Juniperus* sp.
127	Board	O0431		Juniper	*Juniperus* sp.
128	Board	O0433		Juniper	*Juniperus* sp.
129	Board	O0435		Juniper	*Juniperus* sp.
130	Cross piece	O0588	3—Roof (1st Panel)	Cedar of Lebanon	*Cedrus libani A.Rich.*
131	Cross piece	O0590		Cedar of Lebanon	*Cedrus libani A.Rich.*
132	Board	O0591		Juniper	*Juniperus* sp.
133	Board	O0593		Juniper	*Juniperus* sp.
134	Board	O0240	3—Roof (2nd Panel)	Juniper	*Juniperus* sp.
135	Board	O0241		Juniper	*Juniperus* sp.
136	Board	O0243		Juniper	*Juniperus* sp.
137	Board	O0246		Juniper	*Juniperus* sp.
138	Cross piece	O0247		Cedar of Lebanon	*Cedrus libani A.Rich.*
139	Cross piece	O0379	4—Roof (1st Panel)	Cedar of Lebanon	*Cedrus libani A.Rich.*
140	Board	O0382		Juniper	*Juniperus* sp.
141	Board	O0383		Juniper	*Juniperus* sp.

Table 1. *Cont.*

Sample Number	Piece Name	Excavation Number	Location	Identification	
				English Name	Botanical Name
142	Cross piece	O0223	4—Roof (2nd Panel)	Cedar of Lebanon	*Cedrus libani A.Rich.*
143	Board	O0224		Juniper	*Juniperus* sp.
144	Board	O0227		Juniper	*Juniperus* sp.
145	Board	O0229		Juniper	*Juniperus* sp.
146	Board	O0436	5—Roof (1st Panel)	Juniper	*Juniperus* sp.
147	Board	O0439		Juniper	*Juniperus* sp.
148	Board	O0440		Juniper	*Juniperus* sp.
149	Cross piece	O0443		Cedar of Lebanon	*Cedrus libani A.Rich.*
150	Cross piece	O0444		Cedar of Lebanon	*Cedrus libani A.Rich.*
151	Cross piece	O0445		Cedar of Lebanon	*Cedrus libani A.Rich.*
152	Cross beam	O0005	Timber	Cedar of Lebanon	*Cedrus libani A.Rich.*
153	Cross beam	O0064		Cedar of Lebanon	*Cedrus libani A.Rich.*
154	Cross beam	O0672		Cedar of Lebanon	*Cedrus libani A.Rich.*
155	Cross beam	O0673		Cedar of Lebanon	*Cedrus libani A.Rich.*
156	Cross beam	O0131		Cedar of Lebanon	*Cedrus libani A.Rich.*

Table 2. Sample number, piece name, excavation number, and species identification for the canopy elements.

Sample Number	Piece Name	Excavation Number	Identification	
			English Name	Botanical Name
1	Beam	O0215	Cedar of Lebanon	*Cedrus libani A.Rich.*
2	Beam	O0670	Cedar of Lebanon	*Cedrus libani A.Rich.*
3		O0676	Cedar of Lebanon	*Cedrus libani A.Rich.*
4	Pillar	O0773	Cedar of Lebanon	*Cedrus libani A.Rich.*
5	Pillar Base	O0797	Cedar of Lebanon	*Cedrus libani A.Rich.*
6	Pillar Base	O0827	Cedar of Lebanon	*Cedrus libani A.Rich.*
7	Pillar	O0886	Cedar of Lebanon	*Cedrus libani A.Rich.*
8	Pillar	O0889	Cedar of Lebanon	*Cedrus libani A.Rich.*
9	Cross beam	O0892	Cedar of Lebanon	*Cedrus libani A.Rich.*
10	Pillar	O0973	Cedar of Lebanon	*Cedrus libani A.Rich.*
11	Pillar	O0989	Cedar of Lebanon	*Cedrus libani A.Rich.*
12	Pillar	O0992	Cedar of Lebanon	*Cedrus libani A.Rich.*
13	Pillar	01113	Cedar of Lebanon	*Cedrus libani A.Rich.*
14	Cross beam	01119	Cedar of Lebanon	*Cedrus libani A.Rich.*
15	Cross beam	01121	Cedar of Lebanon	*Cedrus libani A.Rich.*
	Pillar	01124	Cedar of Lebanon	*Cedrus libani A.Rich.*
16		01125	Cedar of Lebanon	*Cedrus libani A.Rich.*
17	Pillar	01126	Cedar of Lebanon	*Cedrus libani A.Rich.*
18		01130	Cedar of Lebanon	*Cedrus libani A.Rich.*
19	Pillar	01131	Cedar of Lebanon	*Cedrus libani A.Rich.*
20	Cross beam	01133	Cedar of Lebanon	*Cedrus libani A.Rich.*
21	Pillar	01141	Cedar of Lebanon	*Cedrus libani A.Rich.*
22	Pillar	01144	Cedar of Lebanon	*Cedrus libani A.Rich.*
23	Pillar	01157	Cedar of Lebanon	*Cedrus libani A.Rich.*
24	Pillar	01163	Cedar of Lebanon	*Cedrus libani A.Rich.*

Table 3. Sample number, piece name, excavation number, and species identification for the forecastle elements.

Sample Number	Piece Name	Excavation Number	Identification	
			English Name	Botanical Name
1	Cross beam	O0078	Christ's thorn	*Ziziphus spina-christi* (L.) *Willd.*
2	Board	O0079	Cedar of Lebanon	*Cedrus libani A.Rich.*
3	Board	O0080	Cedar of Lebanon	*Cedrus libani A.Rich.*
4	Board	O0081	Cedar of Lebanon	*Cedrus libani A.Rich.*
5	Board	O0082	Cedar of Lebanon	*Cedrus libani A.Rich.*
6	Board	O0083	Cedar of Lebanon	*Cedrus libani A.Rich.*
7	Board	O0084	Cedar of Lebanon	*Cedrus libani A.Rich.*
8	Cross beam	O0085	Christ's thorn	*Ziziphus spina-christi* (L.) *Willd.*
9	Cross beam	O0088	Christ's thorn	*Ziziphus spina-christi* (L.) *Willd.*
10	Cross beam	O0089	Christ's thorn	*Ziziphus spina-christi* (L.) *Willd.*
11	Cross beam	O0090	Christ's thorn	*Ziziphus spina-christi* (L.) *Willd.*
12	Pillar	O0091	Cedar of Lebanon	*Cedrus libani A.Rich.*
13	Pillar	O0092	Cedar of Lebanon	*Cedrus libani A.Rich.*
14	Pillar	O0093	Cedar of Lebanon	*Cedrus libani A.Rich.*
15	Pillar	O0094	Cedar of Lebanon	*Cedrus libani A.Rich.*
16	Pillar	O0095	Cedar of Lebanon	*Cedrus libani A.Rich.*
17	Pillar	O0096	Cedar of Lebanon	*Cedrus libani A.Rich.*

4.1. Cedar of Lebanon (Cedrus libani A.Rich.)

The features that were crucially diagnostic in the identification of *Cedrus libani A.Rich.* are gradual change from early wood to late wood with arrow of tangentially orientated traumatic resin canals (Figure 5 a,b), and rays uniseriate and, in part, 2–3 seriate with the presence of radial resin duct in very large rays (Figure 5 c,d). In addition, Bordered pits with scalloped tori and cross fields of taxodioid type are in radial walls of tracheids (Figure 5 e,f) [19].

Cedrus libani A.Rich. is a large tree; it can reach 40 m in height and 1–2 m in diameter. The native range of *Cedrus libani A.Rich.* is from Lebanon to Turkey and Cyprus [20], so it was most probably imported from the mountains of Lebanon, as the Lebanese commercial route was so common in the predynastic period that the Egyptian sea-going vessels were also known as "Byblos (Lebanon) boats", from the name of the Lebanese port town entrepôt of Mediterranean and Aegean commerce [21]. The wood from the cedar of Lebanon was used in ancient Egypt for the construction of royal boats, such as the first boat of King Khufu (2589–2566 BC; Old Kingdom [6,8,9] the Dahshour boats of King Senwosret III (ca. 1874–1855 BC; Middle Kingdom [10] and the Gawasis boats (ca. 1850 and 1950 BC) from Mersa/Wadi Gawasis on the Red Se [22] In addition, from the predynastic period, cedar of Lebanon was extensively used for the construction of different artifacts (e.g., coffins, shrines, model boats, and couches [20,23–25].

Cedar wood was considered to be among the most valuable woods for construction as the heartwood was characterized by high durability against fungi and resistance to attack by insects. It also has a high degree of dimensional stability and structural efficiency, as well as good resistance to shock loads and bending strength [26,27]. In addition, it had a very high reputation as a precious raw material due to its excellent technological characteristics, such as straight grained, aromatic, very durable, and taking a good polish. Moreover, it could supply long, straight logs that can reach 40 m in height for constructio [2,20,25,28] Such properties made cedar wood a favored choice in ancient Egypt for making ships and high-status coffins and other funerary artifacts. As a result, the use of cedar for making all the pillars and beams of the canopy, beams of the deckhouse, and pillars and boards

of the forecastle of the boat was most suitable and consistent with previous literature and the large quantities of cedar wood arriving in Egypt during the Old Kingdom, which was indicated on the Palermo Stone that describes Sneferu's 40 ships filled with cedar wood, to construct a 100-cubit ship and palace door [29].

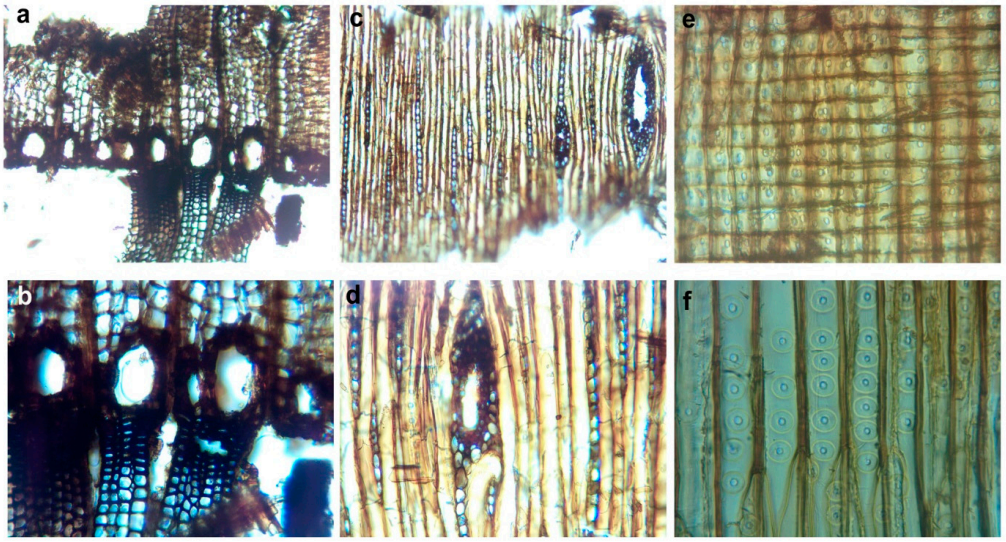

Figure 5. Microphotographs of wood sections under the microscope in transmitted light showing the anatomical characteristics of Cedrus libani A.Rich.: (**a**,**b**) transverse section (TS); (**c**,**d**) tangential longitudinal section (TLS); (**e**,**f**) radial longitudinal section (RLS).

4.2. Juniper (Juniperus sp.*)*

The features that were diagnostic in the identification of *Junipreus* sp. are the gradual transition from earlywood to latewood and the presence of axial parenchyma cells filled with brown extractives in the transverse section (Figure 6a). Rays are uniseriate and, rarely, partly biseriate, and their heights range from 1 to 9 cells filled with substances. In addition, axial parenchyma end walls are nodular, as shown in the tangential section (Figure 6b). In the radial section, ray tracheids are absent, cross-field pitting is cupressoid, the horizontal walls of ray parenchyma cells are smooth, and end walls are nodular (Figure 6c).

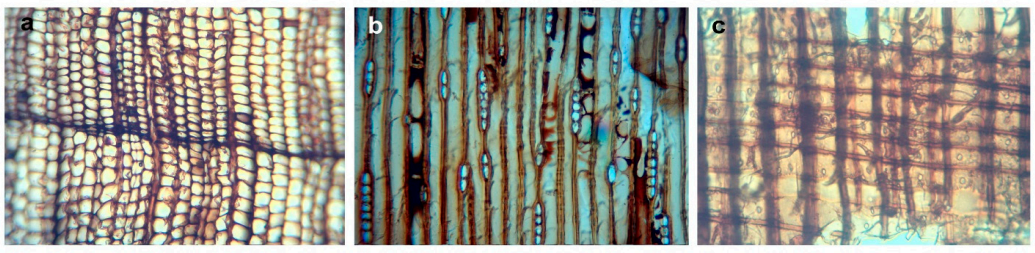

Figure 6. Microphotographs of wood sections under the microscope in transmitted light showing the anatomical characteristics of juniprus sp.: (**a**) transverse section (TS); (**b**) tangential longitudi-nal section (TLS); (**c**) radial longitudinal section (RLS).

The species of juniper, such as *J. phoenicea* (Mediterranean region), *J. excelsa* (South-eastern Europe and from Asia Minor to Pakistan), *J. drupacea Labill* (Greece, Asia Minor, Syria, Lebanon), and *J. foetidissima* (Greece, Asia Minor, Lebanon), are very similar in many anatomical features, such as growth rings, tracheid pits, axial parenchyma, and ray height; therefore, the distinction between certain species is very difficult and any of them could have been used in ancient Egypt [20,28].

Juniperus sp. is a medium tree with straight trunks that can reach 20 m in height and 1–2 m in diameter. Despite the detection of juniper to construct some boards in the first

boa [6] the use of 85% of juniper wood for the analyzed samples of the deckhouse is of interest, in particular, since juniper was rarely used in ancient Egypt. The heartwood from juniper species has a high natural durability, dimensional stability, moderate bending and compression strength, and good workability [30,31]. In addition, it takes a good polish and has a distinctive aroma. Moreover, the wood from juniper is resistant to decay and damage by insects, worms, and fung [20,28] Although juniper wood has some properties similar to those of cedar wood, in particular, the workability, such as polishing, juniper wood has a more distinctive aroma than cedar. In addition, juniper wood has fewer knots than cedar. Furthermore, juniper trees have shorter straight trunks than cedar. Due to these properties, juniper could be a favored choice for making most parts of the royal deckhouse of King Khufu, such as boards, frames, and cross pieces.

Table 4. Anatomical characteristics used for wood identification.

Taxa	Transverse Section (TS)	Tangential Longitudinal Section (TLS)	Radial Longitudinal Section (TLS)
Cedar of Lebanon *Cedrus libani A.Rich.*	Growth rings distinct, transition from early to late wood gradual, and Traumatic resin present. (Figure 5a, b).	Rays uniseriate, and in part 2–3 seriate. Its height is high to very high (more than 30 cells). Presence of radial resin duct in very large rays (Figure 5c, d).	Bordered pits with cross fields of taxodioid type and end walls of ray parenchyma cells distinctly pitted (nodular) (Figure 5e). Scalloped torus margins of bordered pits are in radial walls of tracheids (Figure 5f), which are diagnostic of cedar of Lebanon.
Juniper *Juniperus* sp.	Growth rings distinct, transition from early to late wood gradual, and absence of resin ducts (Figure 6a).	Rays, mostly uniseriate, and its height is low (up to 9 cells) (Figure 6b).	Bordered pits with cross fields of cupressoid type. End walls of ray parenchyma cells distinctly pitted (nodular) (Figure 5c).
Christ's thorn *Ziziphus spina-christi* (L.) *Willd.*	Wood diffuse-porous, and vessels solitary and in radial multiples. Diffuse apotracheal axial parenchyma present. Paratracheal axial parenchyma scanty or vasicentric (Figure 7a)	Rays uniseriate to 3 cells wide (Figure 7b).	Heterocelluar rays with procumbent square and upright cells mixed throughout the ray. Simple perforation plates and inter vessel pits alternate (Figure 7c).
Acacia (*Vachellia* sp.)	Wood diffuse porous. Vessels in multiples (2–3) and sometimes solitary. Paratracheal axial parenchyma vasicentric and confluent.	Multiseriate rays (3–5 seriate).	Homocellular rays with procumbent cells.

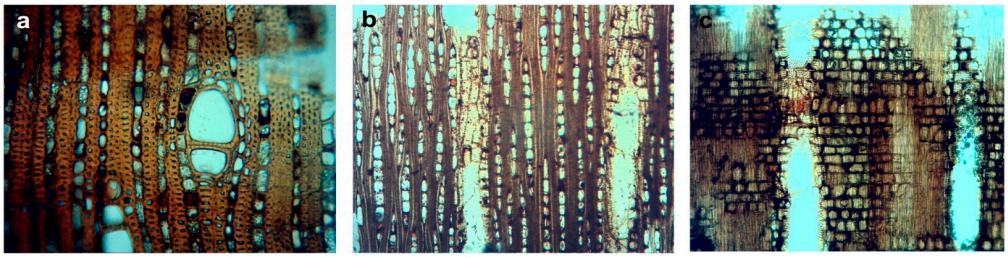

Figure 7. Microphotographs of wood sections under the microscope in transmitted light showing the ana-tomical characteristics of *Ziziphus spina-christi* (L.) *Willd.*: (**a**) transverse section (TS); (**b**) tangential longitudinal section (TLS); (**c**) radial longitudinal section (TLS).

4.3. Christ's Thorn or Sidr (Ziziphus spina-christi (L.) *Willd.)*

Christ's thorn or sidr (*Ziziphus spina-christi* (L.) *Willd.*) is native to Egyp [32] This tree is not large enough to provide the boards that formed the main parts of the large artefacts, but its wood is hard and durable and has a high strength, so it was highly suitable for tool handles, furniture components, tenons, and peg [4,20,33] In ancient Egypt, it was usual to choose woods for the joining elements, which are denser than the boards, and sidr was particularly sought after for creating tight carpentry joins. It was used for making tenons and pegs in the first boat of King Khuf [7–9] so the use of Christ's thorn for tenon production is expected in this study. Surprisingly, the analysis revealed that the presence of 25% of the analyzed samples of forecastle is from *Ziziphus spina-christi* (L.) *Willd.*, which was used for

making cross beams, confirming the previous texts, which showed that ancient Egyptian carpenters tended to reduce the use of high-quality wood, such as cedar of Lebanon, and also often specifically chose woods that were not of the same species as that used for the main part of the artifact. This works well when the different properties of the various species selected respond in a way that creates a tight fit, locking the components together. It also enables hard, dense woods, such as Christ's thorn, which are normally only available as short lengths of timber, to be used to their maximum effectivenes [5,25,34]

4.4. Acacia (Acacia sp./*Vachellia* sp.*)*

Based on phylogenetic studies, *Acacia* sp. was recently reclassifie [35,36] As a result, the new accepted name for this species is *Vachellia* sp.

The features that were crucially diagnostic in the identification of acacia (*Vachellia* sp.) are wood diffuse porous, vessels in multiples (2–3) and sometimes solitary, and paratracheal axial parenchyma vasicentric and confluent. Simple perforation plates, alternate intervessel pits, and vestured pits were present in the radial sections. In addition, rays were pluriseriate (3–5 seriate), exclusively composed of procumbent cells.

Acacia (*Vachellia* sp.) wood is always among the most commonly found trees and was a favored choice in ancient Egypt for making small objects or as pegs and tenons to connect the boards in the ancient Egyptian artifact [3,37,38] Its popularity as pegs and tenons was due to acacia species being normally short and, thus, unlikely to yield timber of sufficient size. Its dimensions sometimes allowed for its use in small objects. In addition, acacia wood is very hard, durable, and heavy, with a high densit [20,34,37,39] Moreover, acacia wood has very high bending and compression strengths [33,40]. As a result, the use of acacia for making pegs was most suitable and in accordance with previous literature.

5. Conclusions

The present work reported the results of the detailed scientific identification of wood species used in the construction of the deckhouse, canopy, and forecastle of King Khufu's second wooden boat (4th Dynasty—Old Kingdom). The analysis confirms that the most frequently utilized timber for the ancient Egyptian wooden forecastle, canopy, and deckhouse parts was the precious softwood of *Juniperus* sp. (Juniper) and *Cedrus libani A.Rich.* (Lebanon cedar) that was widely available at the time of construction. There were only a few other woods found here, but they were all native: *Ziziphus spina-christi* (L.) *Willd.* (Christ's thorn) and *Vachellia* sp. (acacia). The analysis most surprisingly revealed that the presence of 25% of the analyzed samples of forecastle is from *Ziziphus spina-christi* (L.) *Willd.*, which was detected for the first time for making cross beams in the construction of boats in the Old Kingdom of ancient Egypt. An equally interesting aspect of the boat's construction is the presence of *Juniperus* sp., which surprisingly showed the use of almost 85% of the analyzed samples were from *Juniperus* sp., used in the boards, frames, and cross beams of the deckhouse.

The wood from juniper species has some properties similar to cedar wood, particularly workability, including polishing, but juniper wood has a more distinctive aroma and smaller knots than cedar. In addition, it has fewer mechanical properties than cedar. Moreover, juniper trees have shorter straight trunks than cedar trees, which can reach 8 m in height. Due to these properties, juniper could be a favored choice for making most of the panels of the deckhouse, while cedar wood was used for the pillars, beams, and timber structures where load stresses occurred. The findings revealed that ancient Egyptian carpenters were aware of the properties of wood and many factors were taken into consideration when selecting a specific type of wood for making a specific part of the boat, such as size, length, hardness, density, strength, and durability. As a result, the results of our analysis let us implement a database concerning the utilization of wood species in the deckhouse, canopy, and forecastle of the boat in order to provide more information about the ancient technology in boats in the Old Kingdom of ancient Egypt. Finally, further wood identification studies are currently being conducted for the other parts of the second boat, such as oars, hull,

rib, and deck beam, in order to implement the database concerning the utilization of all different timber species in the boat.

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