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REVEALING THE SECOND BOAT OF PHARAOH KHUFU

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A number of pieces from the boat in the second pit matched those in the reassembled first boat, indicating that the two ships were similar. The diagram at bottom locates the pieces in the second pit that have been identified by nautical experts. The cutaway drawing at top shows where these pieces were used in the construction of the first vessel.

As with Khufu’s first ship, the dismantled timbers are probably stacked in a sequence related to the vessel’s finished form. Most of the hull’s structural elements are hidden from view by parts of the deckhouse.

One of the most distinctive features of the first ship was that the planks of the hull were sewn together transversely; most sewn ships are lashed longitudinally. From faintly visible V-shaped grooves on a plank to the far right (1), researchers can tell that the second ship was lashed together in the same way.

A backing timber (2), with a sleeve to accommodate an ornamental end post, indicated that the hull had the same long, narrow shape as that of the first boat. The width and height of the ship’s superstructure can be estimated from the deckhouse panels (3); other panels (4) may be part of the deck. A carrying beam (5), which would support roofing panels and crossbeams, suggests a minimum length for the deckhouse and, by implication, the entire ship. Curved with age are four slender oar blades, one clearly visible (6).
In 1954, a 20 meter heap of rock rubble and wind-blown sand was removed from the southern base of the Great Pyramid of Giza, which was built by Pharaoh Khufu (called Cheops by the Greeks). Removal of the debris over a 2 year period uncovered a wall 2.5 meters wide and one meter high about 18 meters from the pyramid. The wall appeared to cover two groups of neatly hewn blocks of limestone separated by the pyramid's axis. On 26 May 1954, Kamal El-Mallakh, an architect with the Egyptian Antiquities Organization (EAO) was in charge of removing the first of 41 blocks forming the eastern group of blocks. This revealed a cavity 32.5 meters long and 2.5 meters wide that contained the disassembled remains of the oldest planked vessel in the world. Markings on the pit's interior wall indicated that it was sealed by Khufu's son Djedef-Ra, who ruled Egypt after his father's death during the 26th century BC.

The excavation, preservation and reconstruction of this royal ark required 18 years. The ship, which measured 43.4 meters long and 5.9 meters wide at the beam was housed in a specially designed "Boat Museum" built on the site of discovery and opened to tourists in 1982. From the time of the museum's opening the boat had been a great attraction although its original function remains a matter of controversy.

Since its placement in the museum, the exhibited boat had shrunk about half a meter. Conservators believed that this and other signs of deterioration were due to unacceptable environmental conditions inside the museum. Because the second, unopened pit was thought to also contain a boat, much like the first, it was believed that the investigation of its environment would lead to a better understanding of how best to preserve the wood of the exhibited boat. This was the driving force behind the project to investigate the second boat pit. Furthermore, it was believed that the first pit was hermetically sealed. If the second pit was also secured, then sampling of the air inside would uncover important data on the composition of the earth's atmosphere 4.5
millenia ago.

In 1985 a project was initiated between the EAG and the National Geographic Society for the "Nondestructive Investigation of the Second Boat Chamber of Pharaoh Khufu". A group of scientists was assembled in "science council" to establish the required tasks. A research plan emerged, which called for: (1) surveying the shape of the chamber and of its contents by remote sensing techniques for the selection of a proper drilling site; (b) drilling a vertical hole in a block of chalky limestone up to two meters thick without using any lubricants or cooling fluids that might contaminate the pit's environment, and with assurances that no air or other gases would be transferred into the pit; (c) sampling the air inside the cavity at different levels making sure that no chlorofluorocarbons (freons) are introduced into the sample and passing the air through filters to separate any pollen grains or other micro-organisms for analysis; (d) measuring the pressure, temperature and relative humidity inside the chamber; (e) photographing the interior with a video system and a 35 mm still camera without raising the temperature inside; and (f) sealing the hole leaving behind sensors to periodically measure the temperature and the humidity inside the cavity.

To accommodate these stringent requirements a unique rotary air lock was designed by Bob Moores of Black & Decker and manufactured at the National Geographic. Upon successful testing, it became the central feature of the drilling/probing operations of the project. Only two elements formed the basis of operation of the air lock: a circular steel plate that was fixed and sealed to the material being drilled; the second and major element was attached on a pivot. The latter element could be rotated 90° so as to either align holes in both elements for drilling and probing, or cover the hole in the fixed plate, sealing the work surface. In the sealed position various drill/probing heads could be safely exchanged by means of a bolted connection at the upper part of the rotating element.
Work at the site commenced on 12 October 1987 by the selection of the 16th block from the eastern end of the pit. The block, made of biochemical chalky limestone with no visible flaws, measured 4.13 meters long and was slightly tapered, being 87 centimeters wide at its south end and 93 centimeters at the north end. Only part of the wall was cleared to expose the block on top of which a scaffold was erected to hoist the equipment. A tent was set up to protect the photographic equipment and video monitors. An area in the center of the block was made approximately level using a mason's adze. The hole location was marked on the long axis of the block, two meters from its north edge. A circular pad half a meter in diameter was made level and smooth using a small angle grinder, a spirit level, and a sanding block. Loose powder with an industrial vacuum cleaner. The surface of the stone was sealed with a thin layer of a two-part epoxy resin, which was allowed to cure overnight. Using the fixed plate as a template, eight holes were drilled into the block for the masonry anchors which were then driven into the holes.

A lead gasket was positioned concentric with the yet-to-drilled main hole. The lead gasket formed an inner barrier to the possible emission of fumes from the neoprene perimeter seal. As a further precaution against the introduction of contaminants to the pit's air, the volume between the primary lead seal and its surrounding neoprene secondary seal was evacuated to about ½ atmosphere. This "leak scavenging" partial vacuum was also maintained between redundant seals at the fixed plate/rotary plate interface and the double-sealed drill bit shank.

The special design of the drill bit (three concentric tungsten-carbide-tipped masonry core drills) precluded the need to remove a large core segment from the bottom of a deep hole. The 90 millimeter diameter drill bit was driven by a Black & Decker drill with the slow speed of 375rpm to avoid heating of the rock.

Drilling began on October 17 and as the procedure necessitated, only one inch of rock was drilled at a time. A special core-breaking tool was used to snap off the two standing rings and central core of material produced by the triple core bit. These broken fragments, and remaining stone dust, were easily retrieved with the vacuum cleaner. On October 19, with the drill bit reaching a depth of 185 centimeters, the bronze collar suddenly fell, signaling breakthrough.

The drill bit was withdrawn into the air lock that was then turned 90% to seal the drilled hole. The drill head was removed and replaced with the air sampling head. The air probe was stainless steel tube, 3.7 meters long. It could be pushed through two O-ring seals in the probe head to the chosen depth in the pit.

After purging the probe chamber of outside air, the air lock was turned 90° to align the probe with the bore hole. The air probe was inserted into the pit and 70 tiers were pumped from three different levels below the ceiling, to check for stratification of gases. These samples were obtained in six canisters: three round, internally electro-polished stainless steel and the rest cylindrical, deacidified aluminum. All were shipped for analysis at the laboratories of the National Oceanic and Atmospheric Administration (NOAA) in Boulder, Colorado.

During the planning phases of the project, fiber optics, borescopes, all sizes of cameras, and endoscopes were made available from many manufacturers and tested on resolution charts inside a mockup erected at a National Geographic warehouse. We decided on the Rees 93 camera made in Great Britain, which provided a Newvicon tube camera, capable of producing high resolution black and white video images of 550 lines per picture height. A diapogue 300 watt xenon light source
transmitting its light through a 5.8 meter long fiber-optic line provided the answer because the heat from this light source was dissipated above ground.

A second arm contained a modified Canon 35 mm film camera. In addition a video camera was added to provide eyes for the still camera. A small projector bulb provided adequate illumination with a minimum of heat in the pit and enabled the still camera the prime video to capture the scenes on video and film. A modified Vivitar 283 strobe flash was used for the still photo illumination.

Photographs of the interior of the chamber showed stacks of a disassembled boat. Deckhouse panels were clearly visible on top and four slender oar blades were revealed in the eastern end of the pit. The cameras revealed hieroglyphs, much like the quarry marks discovered in the first pit, which gave measurements beneath symbols of height, width and length of ceiling blocks.

The photographs also revealed additional evidence that the pristine environment was violated including: (a) the presence of dark streaks emanating from between blocks along the pit's wall suggested water seepage down the sides; (b) the level of the wood appeared to have been at least 10 centimeters below the original level as indicated by scratch marks on the wall; and (c) a live black desert beetle was revealed on top of the wood.

Regarding environmental measurements, the pressure inside the chamber was identical to that outside. The temperature measured 27°C (81°F). The relative humidity was 85 percent. It is noteworthy that the humidity measured in the first cavity a few days after opening it was 88 percent, indicating perhaps a constantly high humidity in such boat pits.

The Tandem Accelerator of the University of Arizona was used to date a sample of mudbrick retrieved from the base of the wall above the pit. Some archaeologists believed that the wall was ancient, built to surround the pyramid complex. Others believed that its width, and probable original height. The C14 date of about 2,300 BC resolved the issue.

As stated earlier, during pumping from the pit, air was allowed to pass through membrane filters that would capture any pollen grains or bacteria in suspension. These samples were studied by the first author at Boston University; both filters had mineral particles, but no evidence of pollen or bacteria.

Also, three attempts were made to capture from the air organic particles for the identification of any micro-organisms. Antiseptic bottles containing a water and 70% alcohol mixture were brought to the site and air from the cavity was allowed to flow through them.

Three groups took samples for analysis at the Al-Azhar University, the Suez Canal University, and the Egyptian Atomic Energy Establishment. The samples were completely free of microbial contaminants, not a single cell grew in the numerous cultures that were prepared. This may have been because the air was pumped from nearly one meter above the contents of the chamber, whereas bacteria or other organisms may have settled to the bottom of the pit or the upper surface of the wood.

The investigation proved the utility of advanced remote sensing technology in archaeological research in Egypt, and may be applicable to the nondestructive studies of similar sites elsewhere in the world.