Offerings to the Discerning Eye

An Egyptological Medley in Honor of Jack A. Josephson

Edited by

Sue H. D'Auria

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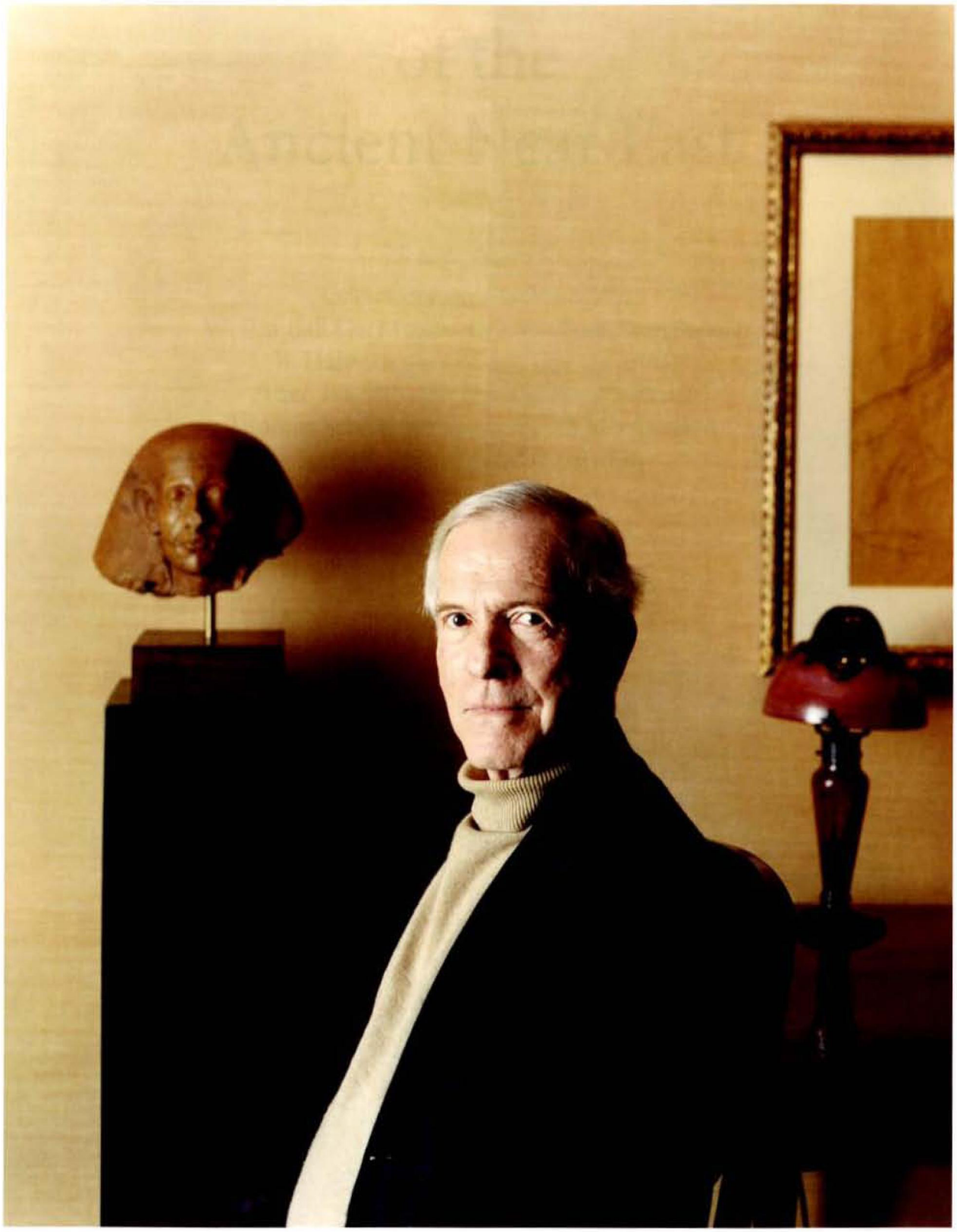

Jack A. Josephson and a Middle Kingdom Nobleman—the Josephson Head

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THE GREAT PYRAMID: THE INTERNAL RAMP THEORY

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Introduction

My involvement with the internal ramp theory is due to Jack Josephson, so I am delighted to be able to contribute this article to his Festschrift. Most of us think of Jack as an art historian, but he also has an engineering degree, and this is primarily an engineering story.

As is well known, the Great Pyramid of Giza is the only member of the Seven Wonders of the Ancient World that remains intact. Serious study of the Great Pyramid began in the seventeenth century, when the Oxford astronomer, John Greaves, visited the pyramid and in 1638 published the first book devoted to it.[1] Greaves, like so many other earlier investigators, believed the Egyptians had advanced knowledge of all kinds of things and encoded this knowledge into the dimensions of the pyramid. During his visit to the pyramid, he took what he believed to be precise measurements (they were considerably off) and discovered the well-like chamber at the base of the Grand Gallery. Greaves's publication stirred others to visit the pyramid, but the next important discovery was made more than a century later.

In 1765 Nathaniel Davison noticed a three-foot hole at the top of the Grand Gallery. When he climbed through it, he discovered the first relieving chamber above the King's Chamber. He did not, however, realize that there were four other relieving chambers higher up.

The next discovery inside the pyramid came in 1835, when Captain G. B. Caviglia cleared both the descending passageway and the well discovered by Greaves and found that they connect. It is now generally agreed that the "well" was dug to provide air for the workers excavating the descending passageway. Colonel Howard Vyse conducted extensive explorations in and around the Great Pyramid from 1836-40, making the most important discoveries of the nineteenth century. Finding a crack in Davison's relieving chamber, he blasted above it and discovered more relieving chambers that he named: Wellington's Chamber, Lady Arbuthnot's Chamber, and Campbell's Chamber. In these relieving chambers, Vyse also found the now-famous graffiti associating Khufu with the pyramid. Also of great importance, he discovered beneath the rubble at the base of the pyramid two of the original casing stones and was thus able to determine for the first time the exact angle of the pyramid's sides.[2]

Probably the most eccentric of the nineteenth-century investigators was Piazzi Smyth, the Astronomer Royal of Scotland, who believed that the pyramid was basically a Christian monument whose measurements contained Biblical revelations.[3] In spite of his extreme religious beliefs, Smyth was also a capable scientist and in 1864 conducted the most detailed survey of the pyramid up to that time. He even invented a miniature eight-inch camera so he could photograph in the smallest of crevices.

Smyth's expedition was a remarkable combination of exacting science and delusion. When he first published his findings in 1867, they were universally rejected by the scientific community as the rantings of a religious fanatic. Still, his theory of revelations built into the Great Pyramid did not die easily, and the next surveyor of the Great Pyramid, Flinders Petrie, became interested only because his father was a believer.

Petrie's father, a mechanical engineer, had read Piazzi Smyth's book and became infatuated with the Great Pyramid and Smyth's idea of divine inspiration. Young Petrie grew up hearing about his father's plans to do a proper survey. For twenty years the father procrastinated, and in the

[1] J. Greaves, *Pyramidographia* (London, 1646).

[2] H. Vyse, *The Pyramids of Gizeh*, 3 vols. (London, 1842).

[3] C. P. Smyth, *Our Inheritance in the Great Pyramid* (London, 1880).

meantime, Flinders became a proficient surveyor and conducted the first careful documentation of Stonehenge. In November of 1880, following in the footsteps of Smyth, 26-year-old Flinders Petrie embarked for Egypt accompanied by crates of scientific instruments.

Using a theodolite and a telescope, Petrie used the surveyor's system of triangulation to take thousands of measurements all over the Giza Plateau. To ensure accuracy, he sometimes took the same measurement a dozen times. Inside the pyramid, he used a plumb line to determine the vertical and measured the walls at various heights to detect if there were even the tiniest of construction errors. Petrie was amazed at the precision of the Great Pyramid's construction, and his measurements and observations[4] are, until today, the basis of many discussions of the pyramid's dimensions. Usually level headed, Petrie got carried away when he measured the granite sarcophagus inside the burial chamber. Because granite is so hard, and because the sarcophagus was so finely crafted, Petrie concluded that the ancients had drills and saws embedded with diamonds. Still, his survey is the foundation of much of the later work on the pyramid.

The Crane Theory

There are two basic theories of how nearly two million blocks of stone averaging two and one-half tons were raised during the construction of the Great Pyramid: cranes and ramps. The crane theory has its origins with Herodotus, who mentions that levers were used to raise the blocks.[5] When this theory is discussed, something like the modern Egyptian *shadouf* is usually imagined. New Kingdom tomb paintings show farmers using *shadoufs*, so we know they were used in ancient Egypt, at least during the New Kingdom, and quite possibly in the Old Kingdom. However, there are several problems with the crane theory. It suggests that hundreds of these cranes were positioned at various levels of the pyramid to lift the blocks. One problem with this is that a tremendous amount of timber would have been needed for these cranes, and Egypt simply didn't have forests to provide the wood. Large timbers for shipbuilding were imported from Lebanon, but this was a very expensive enterprise, so importing enough wood for hundreds of cranes would have been impractical. An even greater problem for the crane theory is that there would not have been adequate room on the pyramid to place all these cranes. The size of the pyramid's blocks tend to decrease in size towards the top; towards the surface of the pyramid sometimes there is only 18 inches of standing room, certainly not enough space for a crane large enough to lift a two-ton stone. So the crane theory can't adequately explain how the blocks were raised, and this takes us to the ramp theory.

The Ramp Theory

Diodorus of Sicily, writing three hundred years after Herodotus, said, "The construction was effected by means of mounds," which is almost certainly a reference to ramps.[6] Although Diodorus never suggested what the ramps might have looked like, Egyptologists have speculated about this for years. One version of this ramp theory is that a ramp was built on one side of the pyramid and as the pyramid grew, the ramp was raised so that throughout construction, blocks could be moved up the ramp all the way to the top (fig. 1). The ramp could have a maximum slope of eight percent, as this is about the limit for men hauling heavy blocks. With an eight-percent slope for the ramp and a height of approximately 480 feet for the pyramid, the ramp would stretch for approximately one mile. Although such a ramp is easy to imagine, there are three basic problems with this theory: 1) A mile-long ramp would have approximately the same volume as the Great Pyramid itself, nearly doubling the time needed to build the pyramid. Also, when the three sides of the pyramid that did not have the ramp were completed, then the ramp would have had to be dismantled, and finally, only after the ramp was dismantled could the face it rested against be completed. This too would add years to the project. 2) The pyramid is on a plateau, and it is not clear where one could put a mile-long ramp. 3) The remains of such a huge ramp have never been found. It is inconceivable that something almost as large as the Great

[4] W.M.F. Petrie, *The Pyramids and Temples of Gizeh* (London, 1883).

[5] Herodotus, *History* (Cambridge, 1990), Book II, 125.

[6] Diodorus Siculus, *Library of History* (Cambridge, 1968), Book I, 63. 4-9.

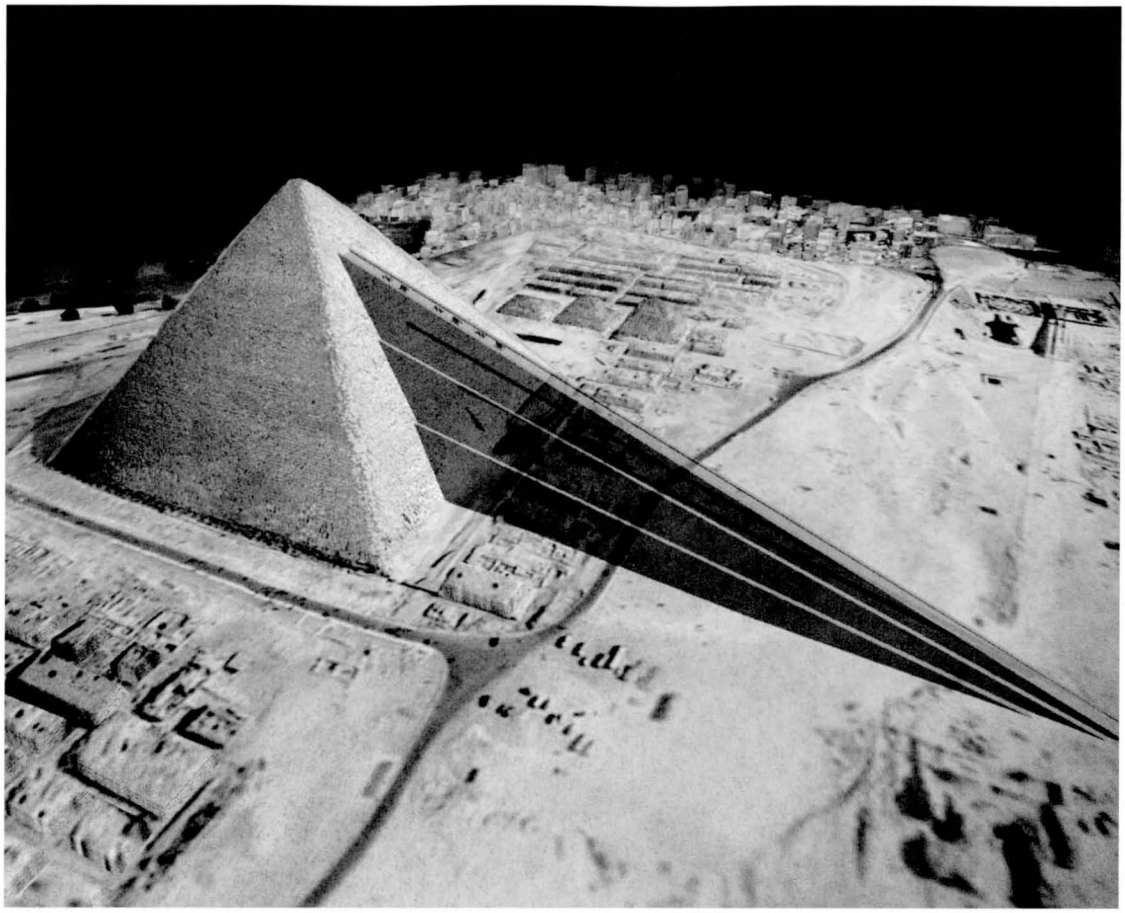

Fig. 1. The single ramp theory. Photograph courtesy of Dassault Systèmes.

Pyramid could have been dismantled and moved so far away that it did not leave clear traces. For these three reasons, it seems unlikely that a single ramp was used to raise the blocks.

The Corkscrew Ramp Theory

Because the straight ramp theory doesn't seem to work, several experts have described a different kind of ramp.[7] This approach suggests that a ramp corkscrewed up the outside of the pyramid, much the way a mountain road spirals upwards (fig. 2). The ramp would still have to be eight percent or less, and a mile long, but we have a place to put it—on the pyramid—and this also explains why the remains of a ramp has never been found; it was part of the pyramid. However, the corkscrew ramp theory also has a serious flaw. With a ramp corkscrewing up the outside of the pyramid, the four corners couldn't be completed till the final stages of construction. The pyramid's builders had to take constant measurements of the angles at the corners to ensure that they were constant as the pyramid rose. If they were off by an inch at the bottom, the pyramid's edges would be off by yards at the top and would not meet in a point. In his definitive work, *Building in Egypt*, Dieter Arnold comments, "During the whole construction period, the pyramid trunk would have been completely buried under the ramps. The surveyors could therefore not have used the four corners, edges, and foot line of the pyramid for their calculations. Furthermore, at a certain height the sides of the pyramid would no longer be wide enough to provide a ramp from one corner to the next."[8] From this consideration, we can see that the corkscrew ramp theory also does not seem practical.

Although almost every writer on the pyramids realizes that the crane theory and both versions

[7] M. Lehner, *The Complete Pyramids* (London, 1997), 215-216.

[8] D. Arnold, *Building in Egypt* (Oxford, 1991), 100.

Fig. 2. The corkscrew ramp theory. Photograph courtesy of Dassault Systèmes.

of the ramp theory are seriously flawed, few have ventured to offer a reasonable alternative. The best attempt is by Arnold, who suggests that a single frontal ramp could have been used for the lower portion of the pyramid's construction (such a smaller ramp would not have had to be a mile long), and then several smaller ramps branched off throughout the pyramid.[9] Arnold is not completely happy with this theory, but it is the best theory offered so far.

The Internal Ramp Theory

The purpose of this paper is to present a new theory that overcomes many of the problems encountered with the theories discussed above. I must emphasize that this theory is not mine in any way. I only became involved in its development because Jack Josephson suggested that its originator, Jean-Pierre Houdin, contact me. Since that initial contact in 2003, my role has been minimal—providing Egyptological background and trying to facilitate the testing of the theory at the site. It will be helpful to understand how the theory arose and how it developed.

Houdin is an architect, but his father, Henri, an engineer, was the first to suggest that the blocks at the top of the Great Pyramid might have been brought up via an interior ramp that remains hidden inside the pyramid today. The architect son realized that many of the details suggested by his father were impractical and soon began refining the theory. It would be reasonable to assume that Jean-Pierre Houdin was able to develop his theory "because he was standing on the shoulders of giants," but this is not really the case. The theory did not develop directly out of the work of others. One reason he has been able to see farther than those before him is that he has made

[9] Ibid., 101.

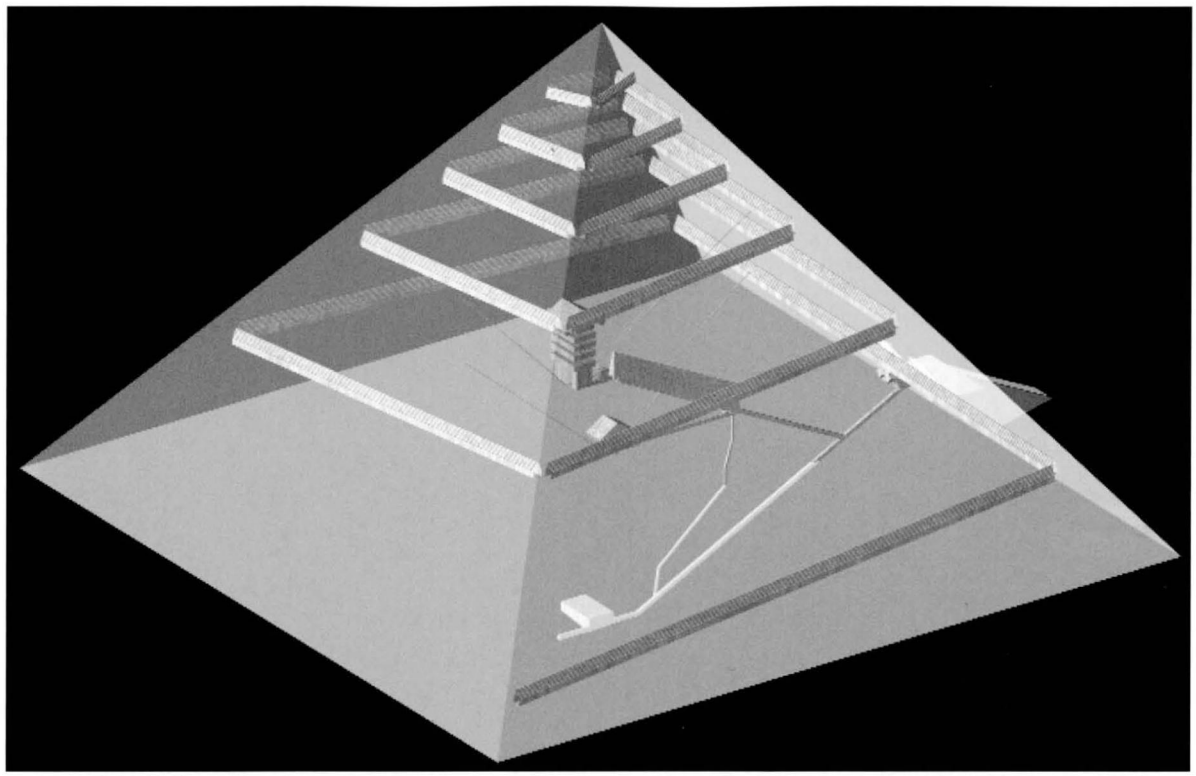

Fig. 3. The internal ramp. Photograph courtesy of Dassault Systèmes.

extensive use of computer software unavailable to earlier researchers. Using programs designed by Dassault Systems for architects, Houdin spent five years building the most detailed 3-D models of the interior and exterior of the Great Pyramid ever created. These models enabled him to visualize and project the pyramid in three dimensions as no other researcher had ever imagined.[10]

Houdin's theory suggests that for the bottom third of the pyramid, the blocks were hauled up a straight, external ramp. This ramp was far shorter than one needed to reach the top, and was made of limestone blocks slightly smaller than those used to build the bottom third of the pyramid. As the bottom of the pyramid was being built via the external ramp, a second ramp, inside the pyramid, was being built, on which the blocks for the top two-thirds of the pyramid would be hauled. This internal ramp begins at the bottom of the pyramid, is about six feet wide, and has a slope of approximately seven percent. The ramp was put into use after the lower third of the pyramid was completed and the external ramp had served its purpose. Not all the upper blocks, however, could be brought up through the internal ramp.

Huge granite slabs were needed for the roof beams of the King's Chamber and the relieving chambers above it. Some of these beams weigh more than 60 tons and are far too large to have been brought up through an internal ramp, so the external ramp had to remain in use until these huge blocks were hauled up it. Once that was done, the external ramp was dismantled and the blocks it was composed of were brought up the pyramid via the internal ramp to the top two-thirds of the pyramid. Thus the top two-thirds of the pyramid were built out of the ramp. Most of the blocks in the upper portion of the pyramid are smaller than in the bottom third, because they had to be brought up through the internal ramp, where space was limited.

Several considerations went into the design of the internal ramp. First, its position had to be selected precisely so that it would not intersect with any of the pyramid's internal chambers or passageways (fig. 3). Second, men hauling heavy blocks of stone up a narrow passageway can't turn a 90-degree corner easily; they need a place ahead of the block to stand and pull. The internal ramp had to provide a means of turning its

[10] J.-P. and H. Houdin, *La Pyramide de Kheops* (Paris, 2003).

Fig. 4. Notches at the corners were left open to help turn the blocks with simple cranes. Photograph courtesy of Dassault Systèmes.

corners; consequently, the ramp had openings at the corners, where a simple crane could turn the blocks (fig. 4).

I have presented Houdin's internal ramp theory in a highly simplified manner because I do not want this paper to be too long. Other aspects of the theory include the function of the Grand Gallery, determining when the roof beams of the King's Chamber cracked, and even when the pyramid's facing stones were set in place. The purpose of this paper is only to discuss the question of how the blocks could have been raised for the construction of the Great Pyramid. The internal ramp theory avoids the pitfalls of the earlier theories, but it is just theory, it shows the blocks *could* have been raised in this manner, not that they *were* raised in this manner. As with any theory it is reasonable to ask, is there any empirical evidence to support it? The answer is "yes."

One bit of evidence is what appears to be one of the ramp's corner notches used for turning the blocks. Two-thirds up the northeast edge, precisely where Houdin's theory predicts there should be one, is a notch (fig. 5). Furthermore, in 1986 a member of a French team that was surveying the pyramid reported seeing a desert fox entering the pyramid through a hole next to the notch, suggesting that there is an open area behind the notch, perhaps the ramp. It seems improbable that the fox climbed more than halfway up the pyramid; more likely there is some undetected crevice toward the bottom where the fox entered the ramp and then made its way up the ramp and exited at the notch. It would be interesting to attach a telemetric device to a fox, send him into the hole, and monitor his movements. The notch is suggestive, but there is another bit of evidence supplied by the French team that is far more compelling.

When the French team surveyed the Great Pyramid, they used microgravimetry, a technique that enabled them to measure the density of different sections of the pyramid, in order to detect hidden chambers. None were discovered, and this seems to contradict Houdin's theory that there is an internal ramp inside. Shouldn't the French have detected it? In 2000 Jean-Pierre Houdin's father was presenting an early version of the internal ramp theory at a scientific conference,

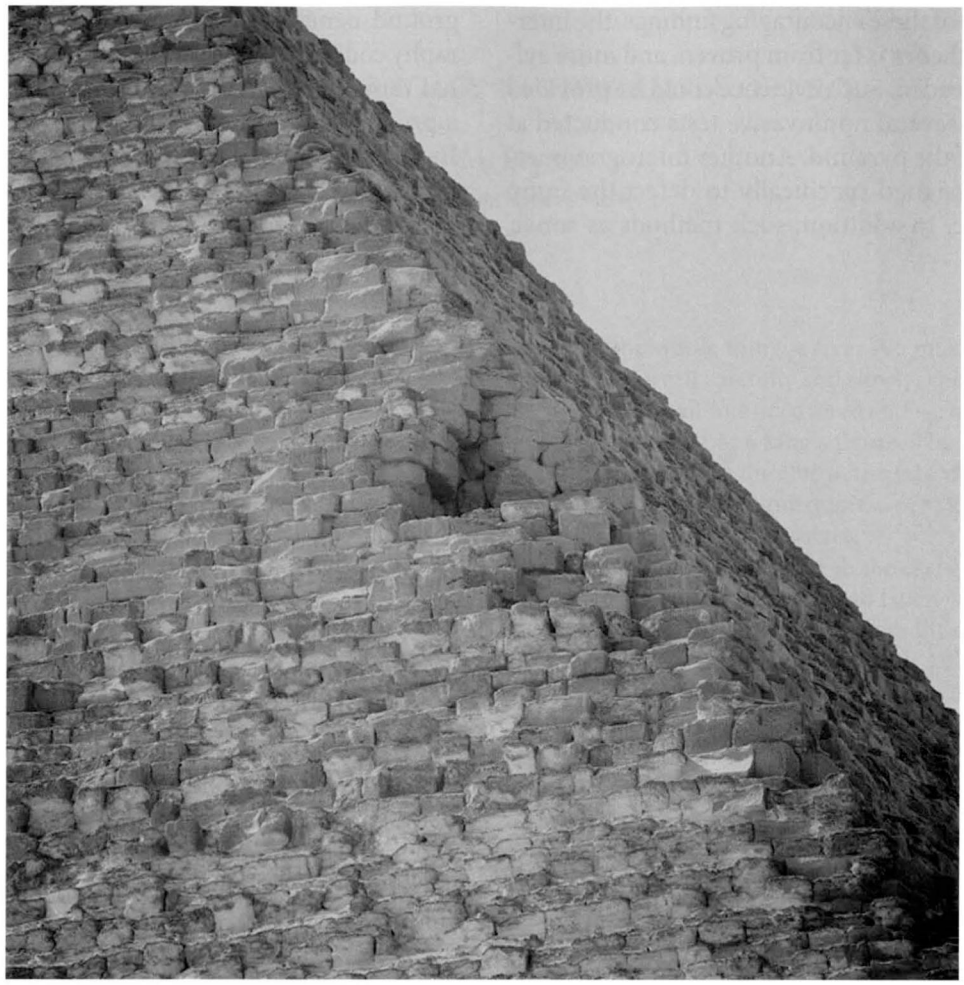

Fig. 5. Possible remains of a notch visible today. Photograph by Pat Remler.

and one of the members of the French team was present. He mentioned to Henri Houdin that the computer analysis of all their data did yield one curious image, something they couldn't interpret. That image showed what Houdin's theory predicted—a ramp spiraling up through the pyramid (fig. 6).

The computer printout of what appears to be the internal ramp is very encouraging. It is important to note that the printout was obtained more than a decade before the internal ramp theory was formulated. In Philosophy of Science it is generally agreed that when evidence for supporting a theory is obtained before or without knowledge of the theory, it is considered stronger than if obtained with knowledge of the theory—no biases could have been involved in the gathering of the data, experimenter fraud can be ruled out, etc., etc. The spiral printout seems to be such a case.

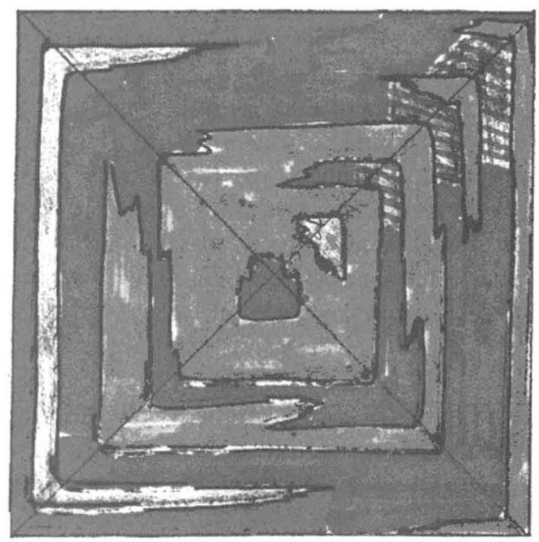

Fig. 6. The French team's microgravemetric image of what appears to be an internal ramp. Photograph courtesy of Fondation EDF.

In spite of these encouraging findings, the internal ramp theory is far from proven, and more evidence is needed. Such evidence could be provided by any of several noninvasive tests conducted at the side of the pyramid. Another microgravimetics test designed specifically to detect the ramp is possible. In addition, such methods as sonar, ground-penetrating radar, and infrared photography could also confirm the existence of an internal ramp inside the pyramid. As of this writing, a proposal for a noninvasive survey of the Great Pyramid has been submitted and we are optimistic that the Supreme Council of Antiquities will grant that request.