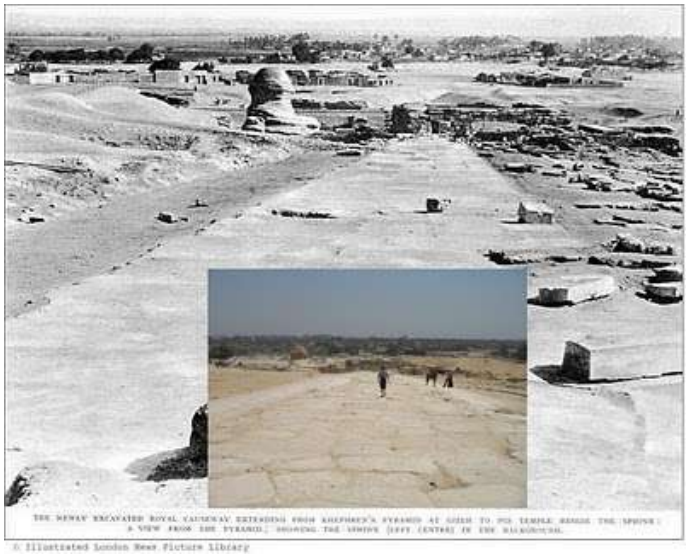
Pyramidales
Em Hotep
Egypt for the Curious Layperson and the Budding Scholar
Théories sur la construction des pyramides égyptiennes

Monday February 21, 2011

Transporting stone blocks and monoliths to construct the Great Pyramid: the ingenuity of Egyptian builders, according to Jean-Pierre Houdin



The « main construction causeway » for the building site

The number “two” has *pride of place in Khufu Reborn (aka Khufu Renaissance), the new version of Jean-Pierre Houdin’s reconstitution of the Great Pyramid’s construction*. After the two ascending corridors (one for the service circuit inside the pyramid, the other for the “Noble Circuit”), the two horizontal corridors (one giving access to the Queen’s Chamber, the other being a section of the “Noble Circuit”), the two antechambers preceding access to the King’s Chamber, two entrances to this chamber and the two levels of the internal ramp, space was made for two external ramps built on the Giza Plateau to transport the materials used to construct the monument (limestone blocks and granite monoliths from the Aswan quarries).
The first of these ramps, qualified as the “main construction causeway”, follows a line east-west towards the position where the Pyramid of Khafre would later be built; its upper part is equipped with a counterweight system. The other continues towards the south face of the Great Pyramid and enters the monument under construction, as a trench, up to the 70 m level.
This is the story of a discovery, in several stages.

A study of the Giza Plateau, together with the technical implications of transporting the materials used to construct the Pyramid of Khufu, led Jean-Pierre Houdin to the following observation: *"Everything on the Giza Plateau proves that the Royal Causeway, connecting the Low and High Temples of the Pyramid of Khafre, was constructed on a ramp that had previously been used for the construction of the Pyramid of Khufu."*

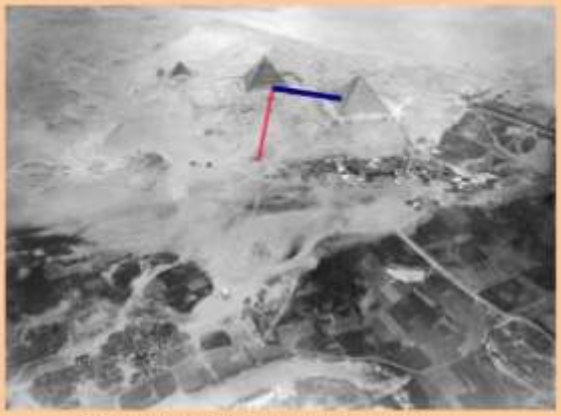
The architect was thus able to provide a significant variant to the theory that he had developed and published in 2007, according to which the Great Pyramid's construction site was supplied from the port following the natural slope of a *wadi* (temporarily dry riverbed), workers obviously dragging the sledges loaded with blocks or monoliths along the gentlest slope.

"*When I presented my 'Khufu Revealed' theory,* Jean-Pierre Houdin tells us, *"I explained that the granite beams for the King's Chamber were hauled up the external ramp using the counterweight system in the Grand Gallery*.

Well, one day I received this message from someone who attended one of my conferences: 'Your counterweight enables the beams to be raised from the base of the external ramp as far as the level of the King's Chamber (+43 m). But how do you get these same beams from the port to your ramp? The distance between them is at least 500 m, and more particularly the port is located 40 m lower than the ramp. Shouldn't you consider a second system to haul the blocks over this distance?' "

This correspondent was right! "If the Egyptians had considered the counterweight solution, they would certainly have applied it to the entire journey made by the beams. A second counterweight would have had to be used to haul the granite blocks from the unloading port for materials coming from Aswan as far as the base of the external ramp. But do traces of its existence still remain?"

A revealing photography



Starting from a higher level on the Giza Plateau, (75 ASL instead of 60 as being supposed up to now), the Khufu ramp (in blue), with a 8,7% slope, slightly more than the first ramp starting from the port (in red), was shorter and less voluminous. The Khufu pyramid being based at 60 ASL, the first 15 meters of this one were built downward up to the horizontal. When the external ramp started to rise, only 28 m in difference of level had to be reached. With a 8,7% slope, its length was only about 325m instead of 425m.

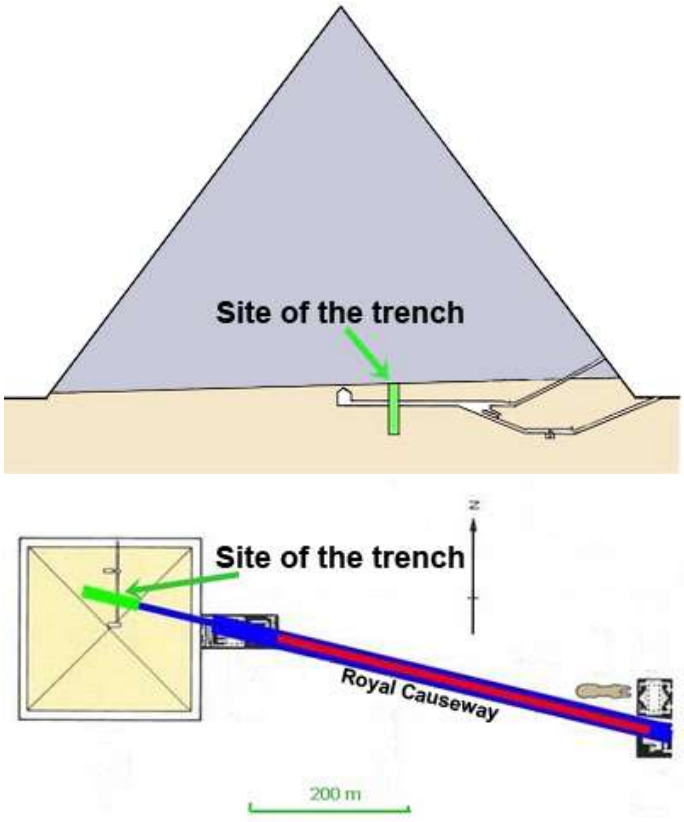
The right questions had been asked. It was now a matter of trying to answer them...
Two days later, the architect discovered a photograph of the Giza Plateau with its three pyramids on the Talking Pyramids website. It was taken in 1905, from a balloon, by the aerostat pioneer Eduard Spelterini.
"*As I was examining this document,*" comments Jean-Pierre Houdin, *"an obvious fact came to me: the royal funeral causeway linking the Low Temple to the High Temple of Khafre's Pyramid had been built on an old ramp. This foundation could only have been used during a construction* project before Khafre's: *that for the Pyramid of Khufu!"*
Days passed... Then, during a recent trip to Egypt, Jean-Pierre Houdin spent long hours studying the topography of the site at Giza, with the aim of checking the accuracy of his intuitions against Spelterini's photographs. He describes his observations:
"*I started by examining Khafre's royal causeway in order to find any clues to the existence of the ancient ramp leading from the port to Khufu's construction site. Then I discovered that this causeway, about ten meters wide, is laid on a perfectly uniform foundation 23 m wide, extending 6.5 m on each side, which is the case neither for Khufu's royal causeway (10 m wide), nor for Menkaure's causeway (8 m wide). Over the better part of the south side, very large limestone blocks were even put into place to fill in hollows.*

"*After walking back up Khafre's royal causeway to its western end, I stood exactly where the external ramp for the Pyramid of Khufu should have started. From there, I was surprised to discover a sort of large slab floor, made of limestone blocks, pointing towards the Great Pyramid. These blocks have nothing to do with Khafre's Pyramid (the transport of the blocks needed to construct this pyramid did not require such an infrastructure), from which I deduced that they would probably have served as the foundation for the external ramp of Khufu's Pyramid.*
"*Moreover, along its route, this ramp serves several of the quarries on the plateau, which supplied most of the materials for the Great Pyramid. This ramp, currently measuring nearly 500 m with a slope of 8.5%, is ideal for the stresses of moving sledges, even more so for dragging beams loaded onto large sledges on rollers.*
"*In my view, the conclusion was obvious: the royal funeral causeway connecting the Low and High Temples of the Pyramid of Khafre had been constructed on an ancient ramp that could only have been used on the previous construction project for the Pyramid of Khufu. King Khafre must have reused a route that had served in the construction of his father's pyramid."*

The counterweight sliding in Grand Gallery

Two counterweight systems

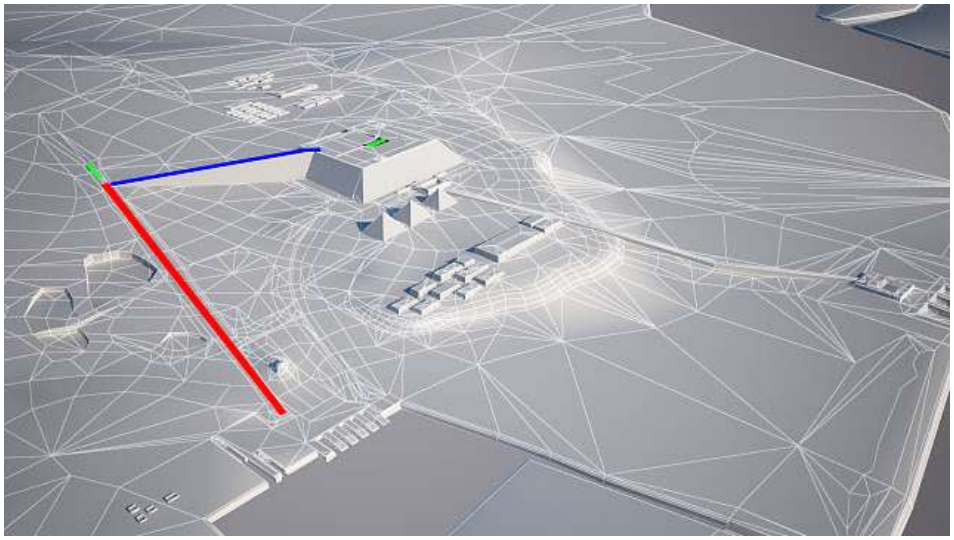
However there remained a problem: human strength alone, which has limits for reasons of co-ordination, could not be sufficient to drag beams weighing up to 63 tonnes the length of this royal causeway. Jean-Pierre Houdin considers that additional force was therefore absolutely essential: the most logical possibility, given the Egyptians' technical knowledge at the time, is that the source of this force would have taken the form of a counterweight moving in a slide channel, a technique enabling human strength to be combined with mechanical force, the mechanical force being "rewound" by human force sequenced in time and space.
But if there had been a counterweight, it was still necessary to find traces of it, proof of its existence... Resuming his observations "on the ground", Jean-Pierre Houdin then took an interest in the configuration of the second Giza pyramid.



From Mark Lehner

"*When you study plans of Khafre's Pyramid,*" he notes, *"you notice that the funeral corridor leading to the King's Chamber was dug into the ground, under the monument, about ten meters below the level of the Plateau in this area. But there is an anomaly in its construction. Over a length of 8 m, the Egyptians did not dig the corridor: they built it, floor, walls and ceilings, in stone. Why? The only plausible explanation is that there was a sizeable hole there, a very deep trench requiring special treatment. Now, if we extrapolate the ramp from the port, or royal causeway, as far as the Pyramid of Khafre, we observe that it crosses the funeral corridor exactly where this construction is found."*

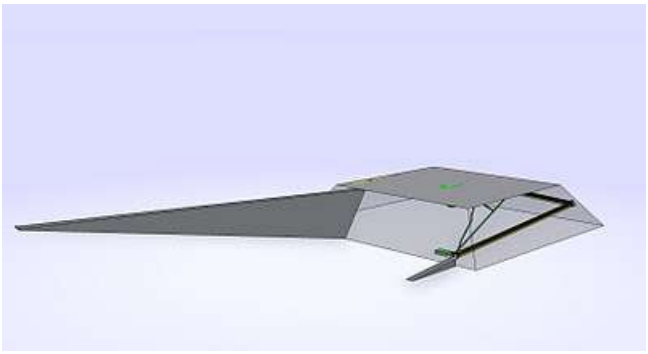
This meant there could be no further doubt for Jean-Pierre Houdin: in the precise line of the royal causeway starting from the port, and toward its higher end, this trench under the Pyramid *of Khafre* had been dug into the bedrock at the time of Khufu, to serve as a slide channel for a counterweight system.



Based on the considerable, not to say indispensable, advantages offered by an external ramp built as *an "expressway",* he understood that the Giza Plateau had been landscaped to provide the following logistical facilities: a direct ramp from the port to the foot of the pyramid's external ramp (**in red on the sketch above**), simplifying and speeding up material supplies to the site; then, as an extension, almost right-angles, a second ramp running towards the south face of the pyramid (**in blue**). The special feature of this system is that its "driving force" relied on two identical counterweight systems (**in green**): "It *was not possible to use human strength alone,"* comments Jean-Pierre Houdin, *"so the architects and engineers decided on the principle of using counterweights from the start of the project, in other words from the design phase. This meant installing two counterweight systems. The first, sited in a trench excavated in the bedrock of the Giza Plateau, to haul the monoliths from the port (level 20 m) to the foot (level 75 m) of the external ramp of the Pyramid of Khufu. A first dragging ramp was built from the port, toward this trench, for this purpose. The second system was sited directly in the heart of the pyramid, between levels +21 m and +43 m: its still visible slide channel, namely the Grand Gallery, is opposite the external ramp that served the construction site up to a maximum level of +43 m."*

An external ramp... extending as an internal ramp

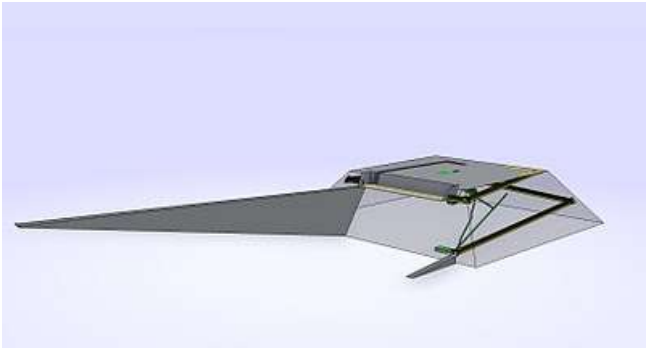
Another new feature then appeared in the reconstitution of the Great Pyramid's construction, the *Khufu Renaissance version*: the configuration of the external ramp extending beyond the royal causeway and heading towards the monument's south face.



External ramp (level 43 m)

Located on a natural promontory of the plateau, the starting point for this ramp was higher than the pyramid's base level. The ramp thus reached a height of 43 m (base of the King's Chamber, with a length of only 325 m. It was extended in a trench, inside the monument, to a height of 70 m (this is new compared with the 2007 hypothesis), the whole thing having a slope scarcely more than 8.5%.
At a height of 70 m, no more than 15% of the volume remained to be built, over an additional 76 m height. This last part of the construction site was out of reach of the external ramp; otherwise it would have been necessary to extend it excessively and make it exceed the volume of the pyramid itself. Hence the solution of the internal ramp, the central idea of the Houdin theory in its first *Khufu Revealed* version.

"*At the start of my research into construction of the Pyramid of Khufu,"* says Jean-Pierre Houdin, *"I thought that the Egyptians had built almost three-quarters of the monument using the external ramp*. *But I was still far away from what they were capable of doing... Discovering the ramp from the port enabled me to position Khufu's external ramp precisely on the ground. Among other things, I noticed that it arrived at the monument at the level of the base of the King's Chamber to the west of the south face, almost at the point where the internal ramp ended. During the construction of the King's Chamber, the pyramid continued to rise normally, except for this southern part where the granite beams were stored.*



External ramp (level 70 m)

"*The external ramp arrived at the south-west corner and continued as a trench in the pyramid by turning clockwise until it reached above the roof of the King's Chamber (+70 m).*

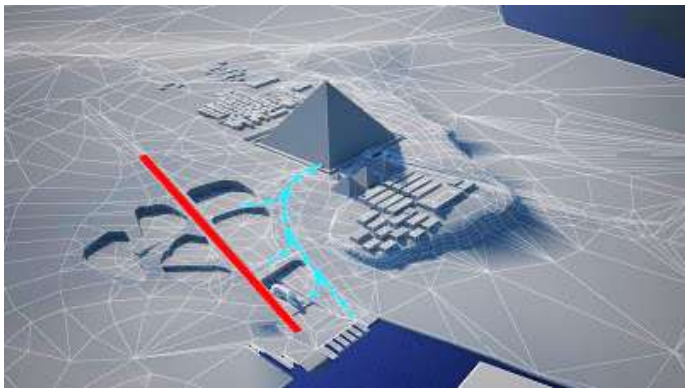
"You must first ask yourself the true questions"

"*The southern part remained at level +43 m while the King's Chamber was built. Construction of the internal ramp was therefore interrupted in this southern part, but the Egyptians' big trick was to continue its construction and use by making it restart from the south-east corner. Thus for several years, teams were dragging sledges on the flat and in the open air at level +43 m, then pulling them up a slope from the south-east corner. When they had finished using the external ramp, the southern part was filled in and a horizontal tunnel was constructed to link the internal ramp from the south-west corner to the south-east corner. This is why, as shown by measurements made in 1986, the section of ramp in this southern part remains horizontal.*

"*By not cutting across the path of the external ramp with the internal ramp during the construction of the King's Chamber, the Egyptian builders had succeeded in constructing 85% of the pyramid's volume by using the external ramp. However this trick had one drawback: part of the internal ramp stayed permanently horizontal at level +43 m, but this was largely compensated for by the fact that there remained no more that 15% of the volume to be constructed. On the other hand, there still remained more than 76 m in height to be completed: this is where the internal ramp played its part to the full*."

Three complementary ramps

In summary, Khufu's Pyramid was built using three separate and complementary ramps: the ramp from the port (future Khafre's royal causeway) used, with its counterweight, as far as the level of the current Pyramid of Khafre; the external ramp, as far as level +43 m of the pyramid, extended by a ramp built in a trench running clockwise as far as the +70 m level; the internal ramp, constructed from the base of the pyramid (south-east side), spiraling counter-clockwise and including a flat part at the +43 m level.
It is precisely onto this flat part (+43 m) that the monoliths for the King's Chamber and the relieving chambers were first raised (using the counterweight in the Grand Gallery), then stored temporarily before being put in place (still using the Grand Gallery counterweight system) at their various levels to form the ceilings of the King's Chamber and the relieving chambers.



The « main construction causeway » (in red) and the natural ramp (in blue)

To complete this logistical configuration of the Giza site, Jean-Pierre Houdin guides us to a final observation, while still keeping an eye on the plateau's topography. This time it is connected with the facing blocks made of Tura limestone delivered to the port and those extracted from quarries excavated around the Sphinx and a little higher up.

There was no need for these blocks to take a detour towards the position where Khafre's Pyramid was subsequently erected. They were quite simply pulled over a small natural ramp (*in blue on the sketch above*) following the incline of the plateau in order to be brought as far as the entrance to the internal ramp located in the southern face of Khufu's Pyramid and about 25 m from its south-east corner. Transported to the foot of the pyramid being constructed, the blocks then began their ascent into the bowels of the monument, following the internal ramp.

"*After filming of the 'Khufu Revealed' documentary in 2008,"* adds Jean-Pierre Houdin, *"and Bob Brier's discovery of a room behind the notch in the north-east ridge, we were able to use 3D modeling of this area to specify the geometry of the internal ramp. This enabled us to understand the role of this room and gave us very precise information about the route of the internal ramp within the pyramid, because we now had several reference points in space: firstly, at the base of the pyramid, the entrance in the south-east area; then the passage above the rafters of the north-face entrance, then again the end at level +43 m under the west face, and finally this room at +81 m in the north-east edge; the horizontal route of the ramp at level +43 m beneath the south face then became evident. By relying on the picture of the density anomaly detected in 1986,and by positioning the entrance to the internal ramp precisely using field observations, I was able to reconstruct the likely route for blocks inside the pyramid.*

"*The first section of the ramp (in blue) is parallel to the face and climbed as far as the first corner chamber in the north-east corner. The second and third sections (the first two white segments) climbed 'at an angle', because as they rose they followed the slope of the pyramid inclined towards the interior. The fourth section located at a height of +43 m (in yellow) is horizontal and parallel to the south face. The following fourteen sections (in white) climb 'at an angle' as far as the summit."*

At each corner of the pyramid, corresponding to the junction between two sections of the ramp, a volume (a room as discovered by Bob Brier) was created to rotate the sledges used to transport the blocks. One of these volumes, under the north-east edge of the pyramid, gave rise to detailed exploration by the American Egyptologist Bob Brier. The results will be presented in a forthcoming article on this blog.

Interview by Marc Chartier