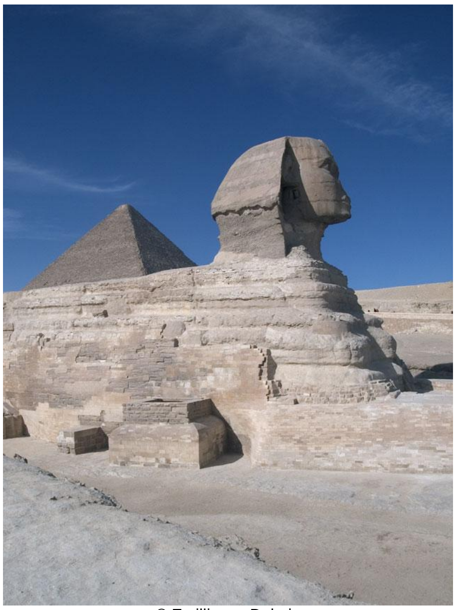
Egypt Fourth Dynasty

# CRITICAL ANALYSIS OF THE GIZA PLATEAU



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Study carried out by Jean-Pierre Houdin

Honorary architect

Paris, February 18, 2010, completed June 8, 2010, May 13, 2013, and August 30, 2016.

# Introduction

Professional and amateur Egyptologists have been constantly debating the enigma of the Sphinx for nearly two centuries in an effort to find a definitive solution:

**With which pyramid is the Sphinx associated and therefore, which king gave it his face?**

Is it linked to that of Khafre (also known as Khafra, Chephren) on the left, or to Khufu (or Cheops) on the right?

The German Egyptologist Rainer Stadelmann carried out a remarkable historical, topographical and morphological study of the Sphinx, which was presented at the Académie des Arts et Belles Lettres in 1999:

http://www.persee.fr/web/revues/home/prescript/article/crai_0065-0536_1999_num_143_3_16044/

Professor Stadelmann concluded very convincingly that the Sphinx could not possibly represent King Khafre and that everything led him to believe with near certainty that it was in fact King Khufu. He also succeeded in demonstrating a trend in Egyptology: “This shows the extent to which our discipline favours written sources even when they are incomplete or doubtful.” All he was missing was irrefutable proof to confirm his conclusion.

This study, relying on analysis of the original topography of the plateau and changes made in different periods, provides this irrefutable proof that the Sphinx on the Giza Plateau was sculpted during the reign of Khufu, in a quarry opened for the construction of the Great Pyramid, and that its face is indeed that of this extraordinary King who reigned in the Fourth Dynasty of Ancient Egypt.

Jean-Pierre Houdin

Paris, 18 February 2010

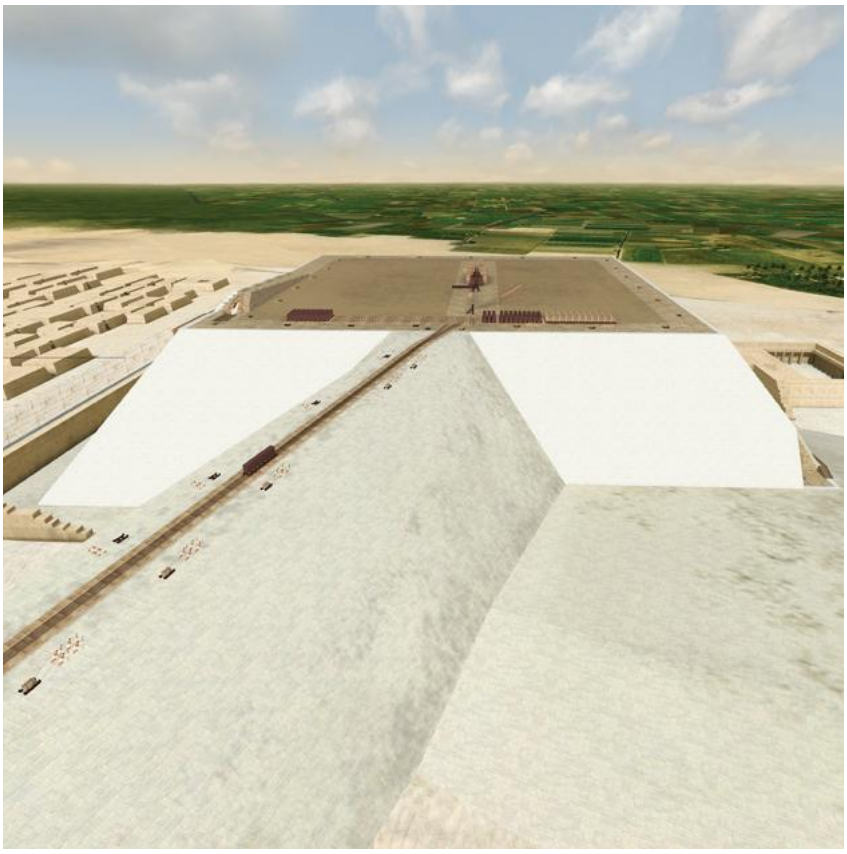
## History of the Royal Causeway of Khafre

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 in the construction of the pyramid of Khufu.

Explanations:

Granite beams and Tura limestone rafters for King Khufu's Chamber, delivered during the first 14 years of construction, were stored in a special area of the port, close to the present Sphinx.

When construction of the pyramid was finished, in around the 14$^{th}$ year, level +43 m (level 103), a very important operation took place, called the first phase: the transfer of all these monoliths from the port to a new storage area prepared at the edge of the south face of the pyramid at this same level.



Raising beams from the base of the exterior ramp up to level +43 m of the pyramid, according to the theory.

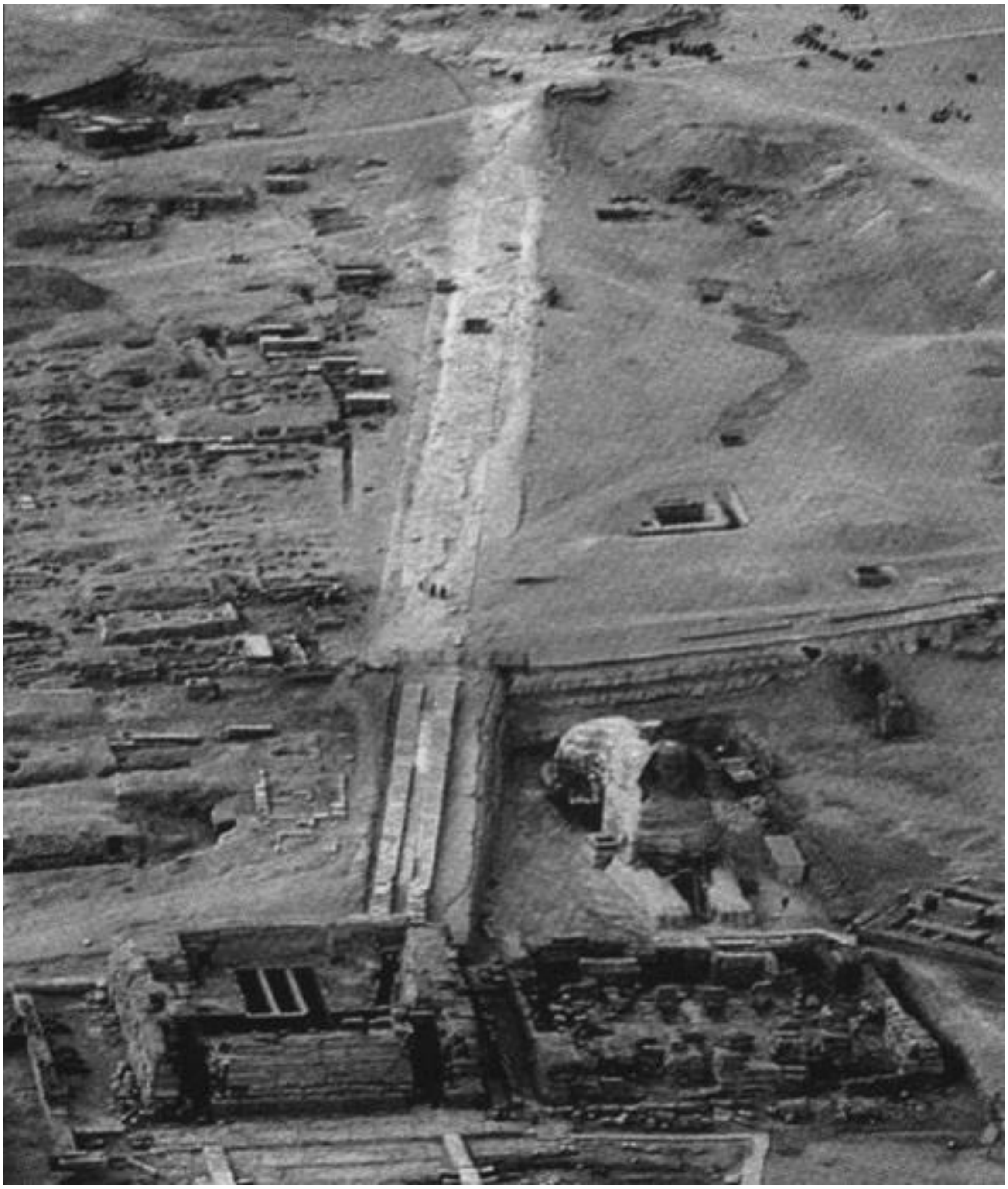
As it was not possible to rely on human force alone, the architects and engineers decided from the project outset, in other words in the design phase, to make use of the counterweight principle. This meant installing two counterweight systems:

- The first, sited in a trench excavated in the bedrock of the Giza plateau itself, for the dragging of monoliths from the port (level 20) to the foot of the exterior ramp (level 73) of the pyramid of Khufu. For this purpose, a first dragging ramp facing this trench was built from the port.
- The second, sited right in the heart of the pyramid, between levels +21 m and +43 m, so that the “slide” is still visible, namely: the Great Gallery, itself facing the exterior ramp serving the construction site up to a maximum level at +43 m.

Analysis of the Giza Plateau as it can be seen today.

East-west aerial view of the Royal Causeway.

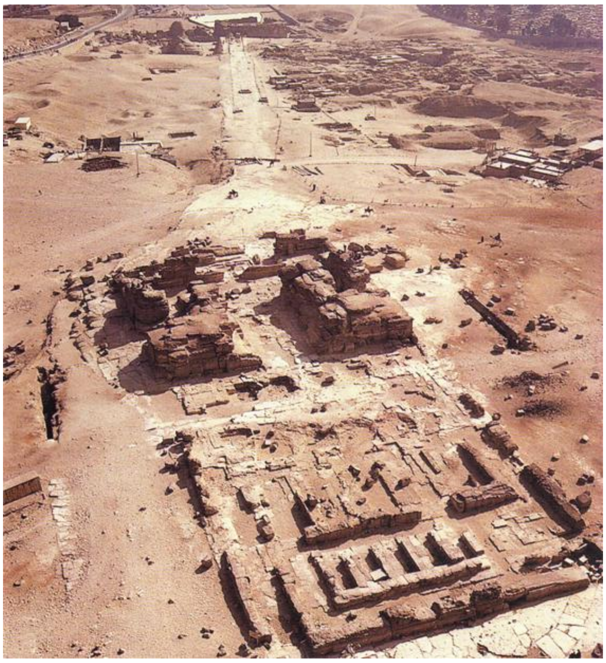
Foreground: the Low Temple of Khafre (left) and the Temple of the Sphinx (right).
Centre: the Royal Causeway of Khafre (centre), the Sphinx in a half-filled quarry (right).



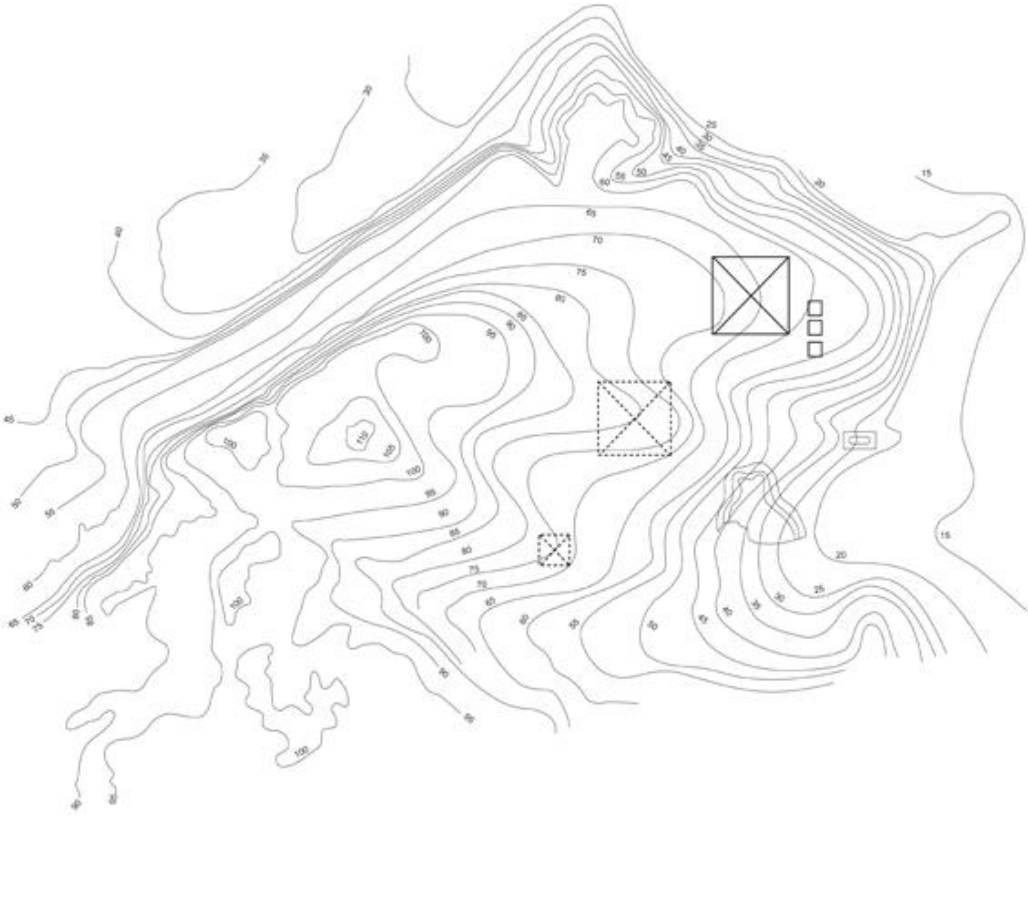
We can clearly see a ramp forming the foundations of the Royal Causeway of Khafre.

West-east aerial view of the Royal Causeway.

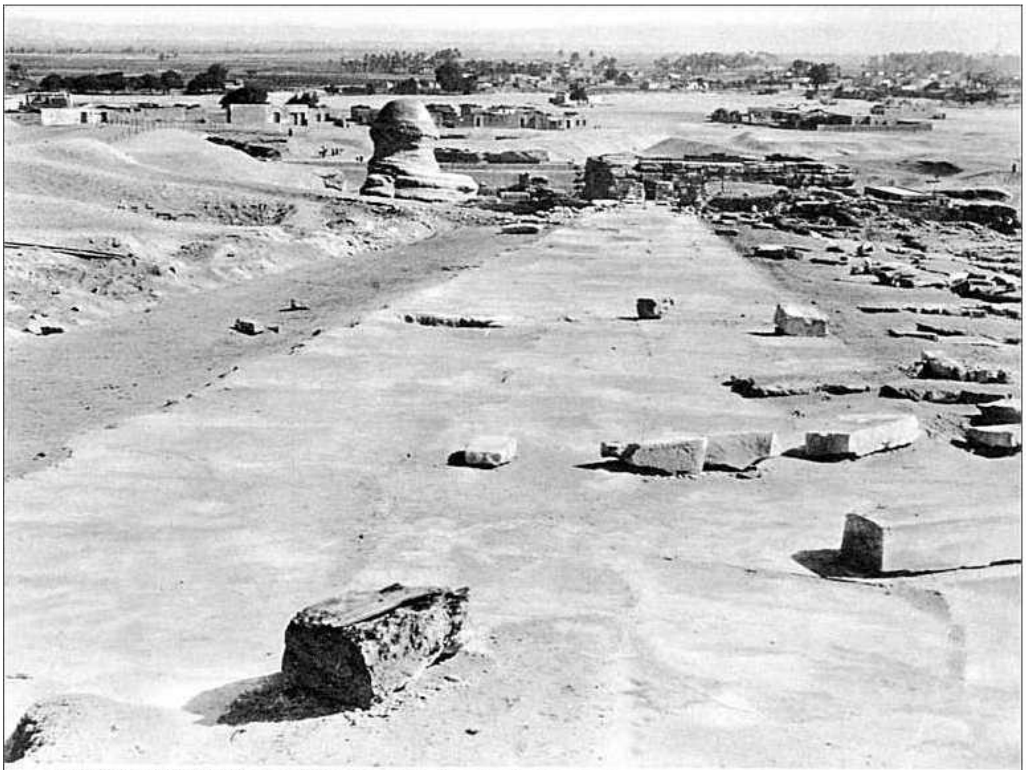
Foreground: the High Temple of Khafre, built on a promontory of the plateau or rocky spur that had been levelled for its construction.
Centre: the Royal Causeway of Khafre
Background: The Sphinx (left) in a half-filled quarry, the Temple of the Sphinx and the Low Temple of Khafre (centre).



The promontory that was levelled for the construction of the Temple must have looked like this: the level of the plateau was thus slightly higher in this place, as shown below.



Old view towards the east of the Royal Causeway (photograph taken halfway along).



THE NEWLY EXCAVATED ROYAL CAUSEWAY EXTENDING FROM KHEPHREN'S PYRAMID AT GIZEH TO HIS TEMPLE BESIDE THE SPHINX: A VIEW FROM THE PYRAMID; SHOWING THE SPHINX (LEFT CENTRE) IN THE BACKGROUND.

© Illustrated London News Picture Library

The foundations of the Royal Causeway are uniform across their entire width, which is much wider than the Royal Causeway itself. This ramp, currently nearly 500 m long with a slope of 8.5%, is ideal for using sleds, even more so for dragging large sled-loads of beams using rollers.

There remains one problem: human force alone, which has limits for reasons of co-ordination, is not enough to drag beams weighing up to 63 t. Additional force is therefore absolutely necessary and the most logical, given the technical knowledge of Egyptians at the time, takes the form of a counterweight running in a slideway. This is a technique that allows this force to be divided into two parts: human force and a mechanical force, the mechanical force being “boosted” by the human force; this latter force, sequenced in time and space, can be reduced each time, hence it is easier to co-ordinate.

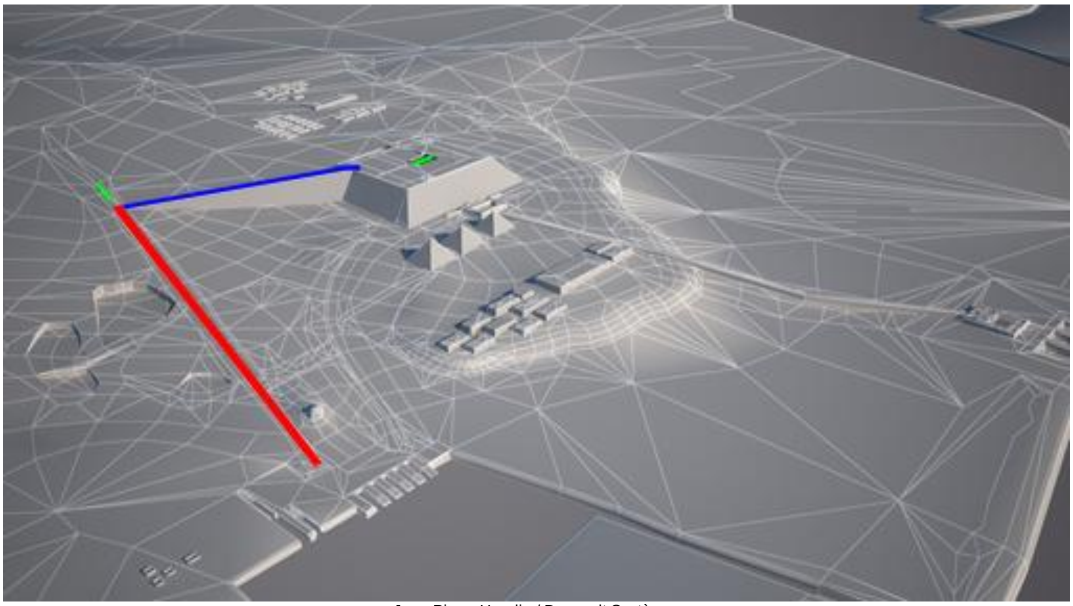
An additional advantage arises: it then becomes possible to drag a load in a uniform and controlled way, thus avoiding jerks. How? By using a tractive force greater than that required and by using human force to brake the counterweight as it descends. The forward speed of the sled is controlled while allowing the workers to slide the rollers continuously under the sled’s runners as it moves forward. The team that resets the counterweight therefore also serves to brake its descent.

The slideway for this counterweight system must have been excavated in the bedrock of the upper part of this causeway and along its extrapolation. It must have looked like two trenches known from this period and still visible today:

The Great Excavation at Zayet El-Ahryan

And the trench of the Pyramid of Djedefre at Abu Rawash.

This type of trench was therefore quite normal for the Egyptians.



Jean-Pierre Houdin / Dassault Systèmes

In red, the harbour ramp with, in green, the sloping trench of the first counterweight system used during the first phase to raise the beams to the base of the outer ramp.
In blue, the outer ramp, starting from the high point of the harbour ramp, allowing these same beams to be raised to the +43m level of the pyramid, with, in green at the center of the monument, the Grande Galerie in which a second, identical counterweight system operated.


Jean-Pierre Houdin / Dassault Systèmes

It should be remembered that in a 2ème phase, in the pyramid itself, the monoliths are transferred from the +43m level to their destination ceiling levels; a wooden transport platform then circulates in a slide built opposite the Grande Galerie, equipped with its counterweight. A whole series of fittings is required for this slideway: two stone side benches with opposing pairs of orifices at regular intervals, notched wooden pieces running laterally, a roller train with its turnbuckle and, finally, a device for anchoring the traction ropes. On the way up, this platform is used to raise a beam; on the way down, it is loaded with small blocks and itself becomes the counterweight of the counterweight.

The trench for the counterweight system on the Giza Plateau was to look as follows:


Jean-Pierre Houdin / Dassault Systèmes

Port and outer ramp junction, end counterweight trench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Pulling area for counterweight rearming in foreground, trench in background.


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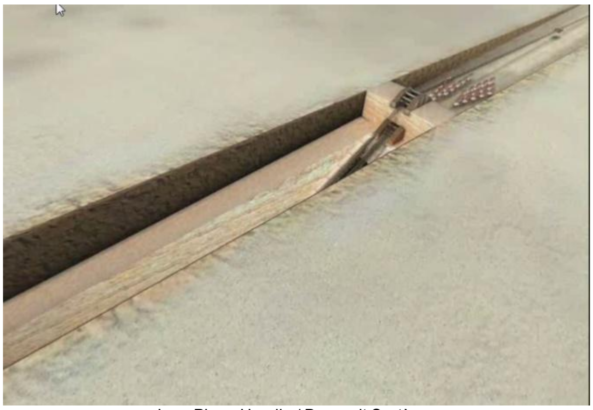
Traction area for counterweight rearmament on right, trench on left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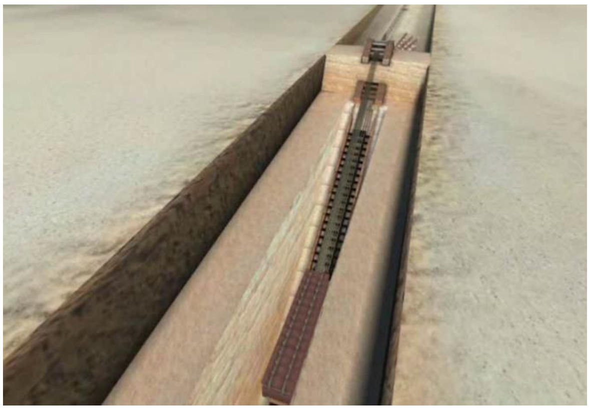
Counterweight trench on left, counterweight rearmament traction area on right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Overhead view of counterweight system in trench


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The counterweight is halfway down the trench cut in the bedrock.

Once all the beams have been stored at the +43m level, the material used in the Plateau trench opposite the harbour ramp during phase 1ère is no longer required, and will be recycled in its entirety to

equip the guardrail to raise the beams to their final position during the second phase
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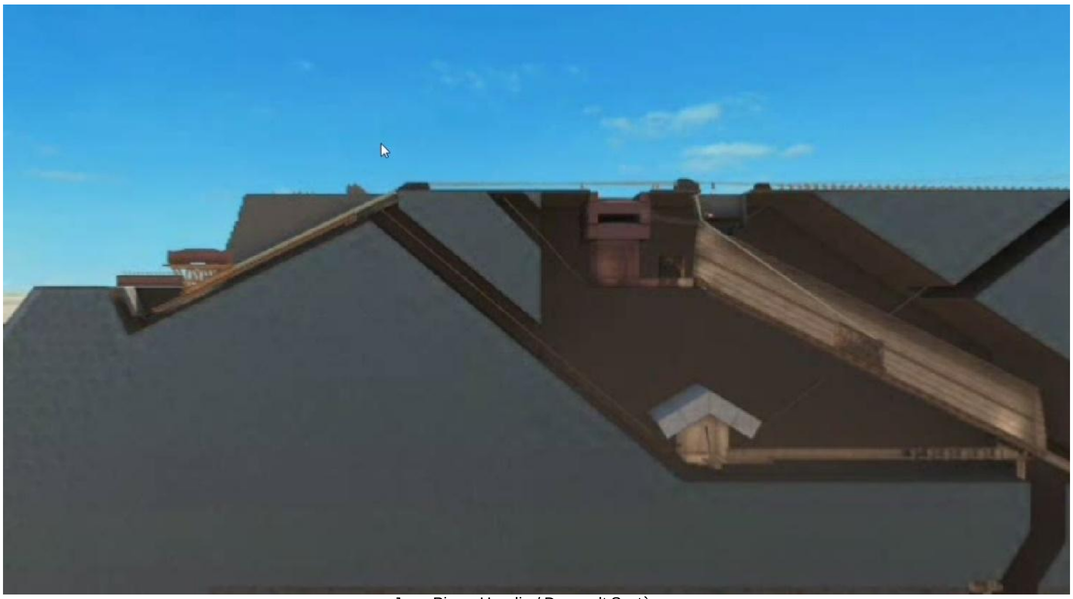
Jean-Pierre Houdin / Dassault Systèmes



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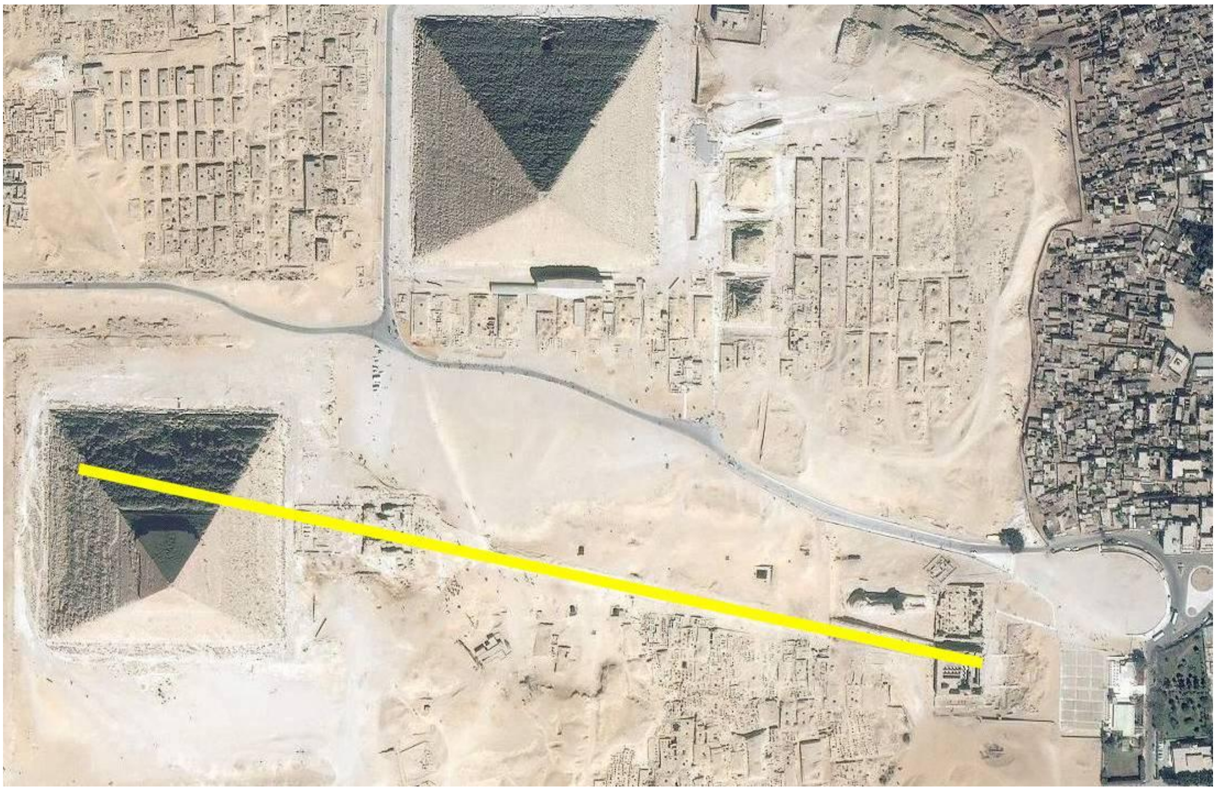
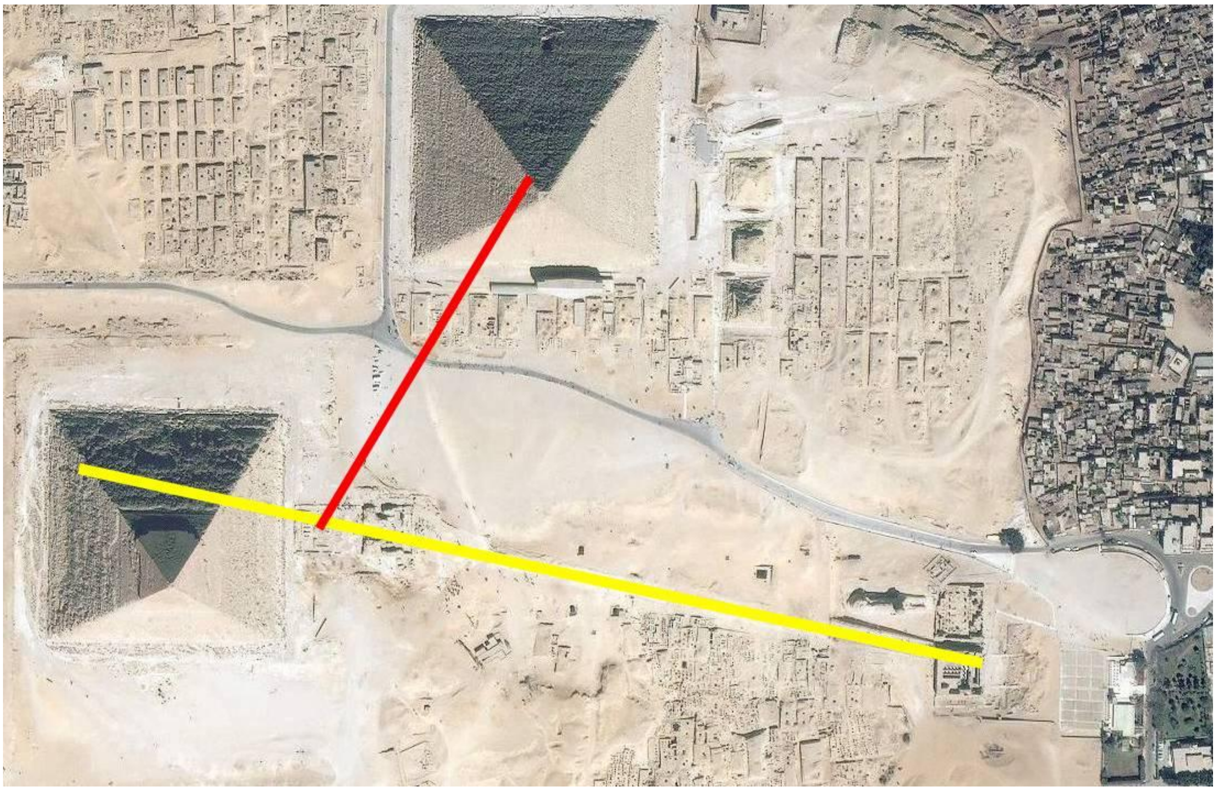
On the left in this illustration, the counterweight system of the harbor ramp, i.e. the platform for the beams, the roller train, the lateral notched timbers, etc., as well as the stones of the benches in this section, is a reuse. On this site, everything was used and reused to the maximum.

Aerial view (Google Earth) of the Giza Plateau.

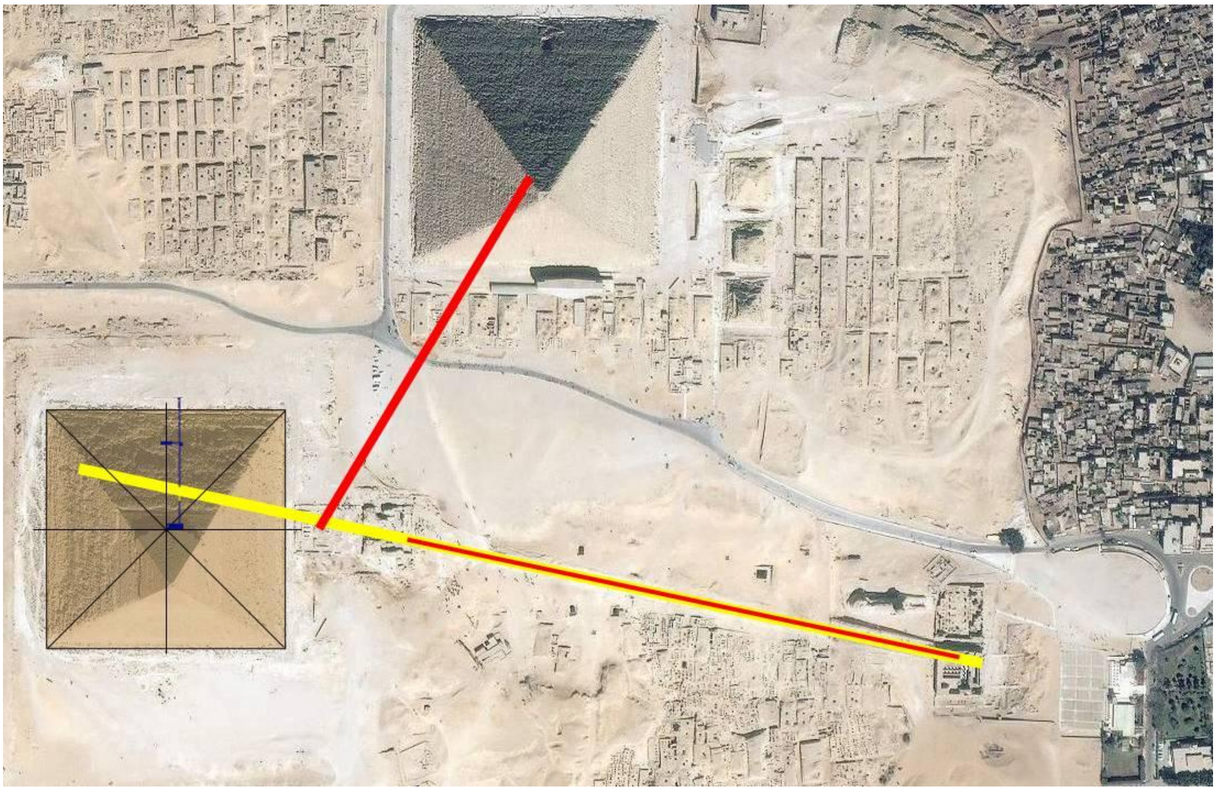
The “slideway” trench for the first counterweight must have been located along the axis of the Royal Causeway of Khafre.



The axis of the exterior ramp of Khufu intersects the Royal Causeway by the High Temple of Khafre.

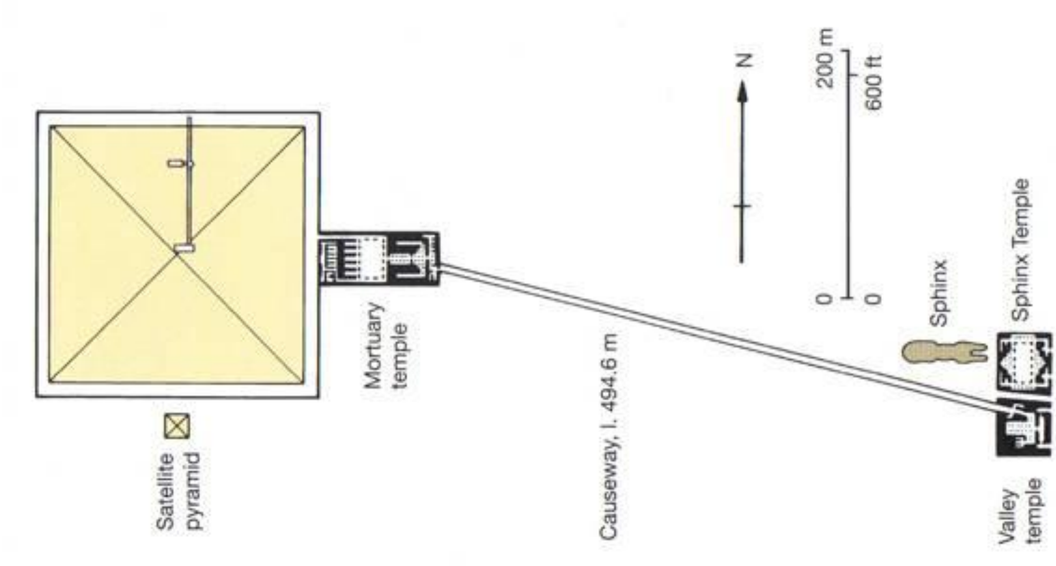


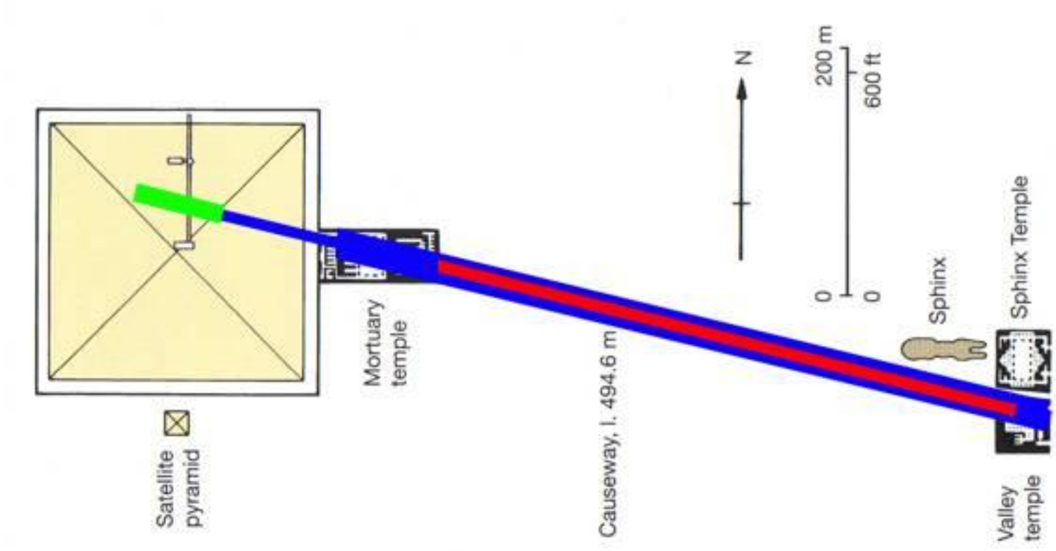
The trench must therefore have been located “under” the present pyramid of Khafre. Superimposed on the picture, the plan of the pyramid of Khafre and its internal structures.



The axis intersects the horizontal corridor of the pyramid of Khafre. This must therefore cut across the trench.

Taking the plan of the mortuary group of Khafre, according to Mark Lehner (Complete Pyramids)



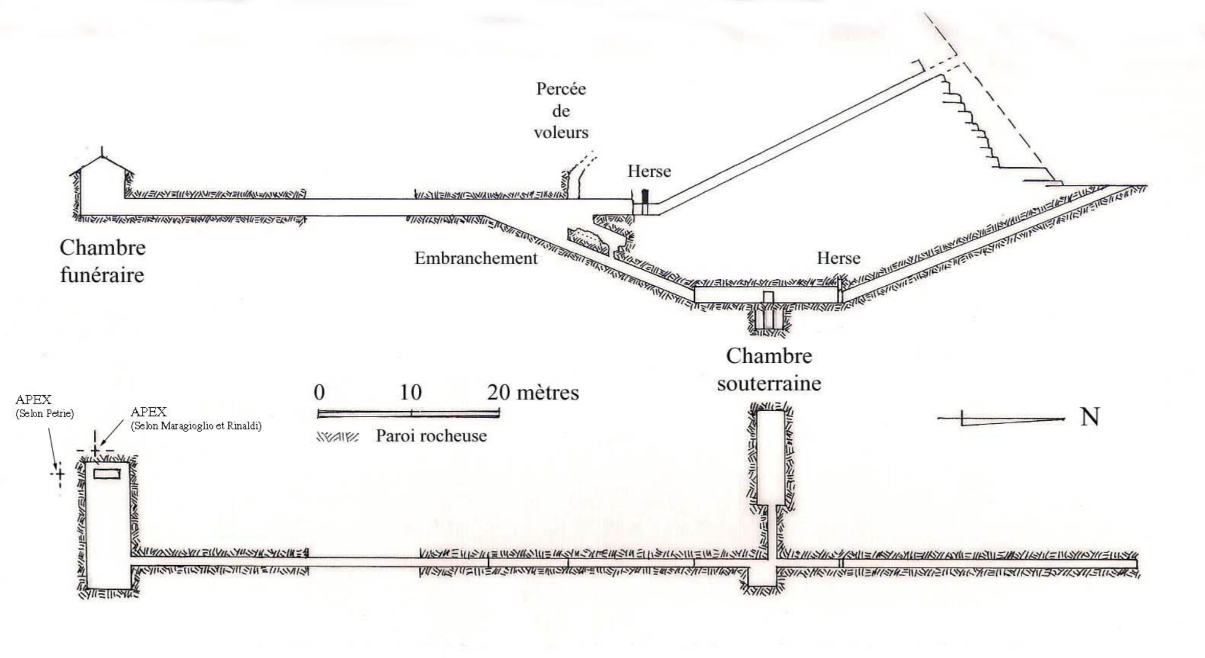




Wide blue: foundation of the causeway (ramp of Khufu)

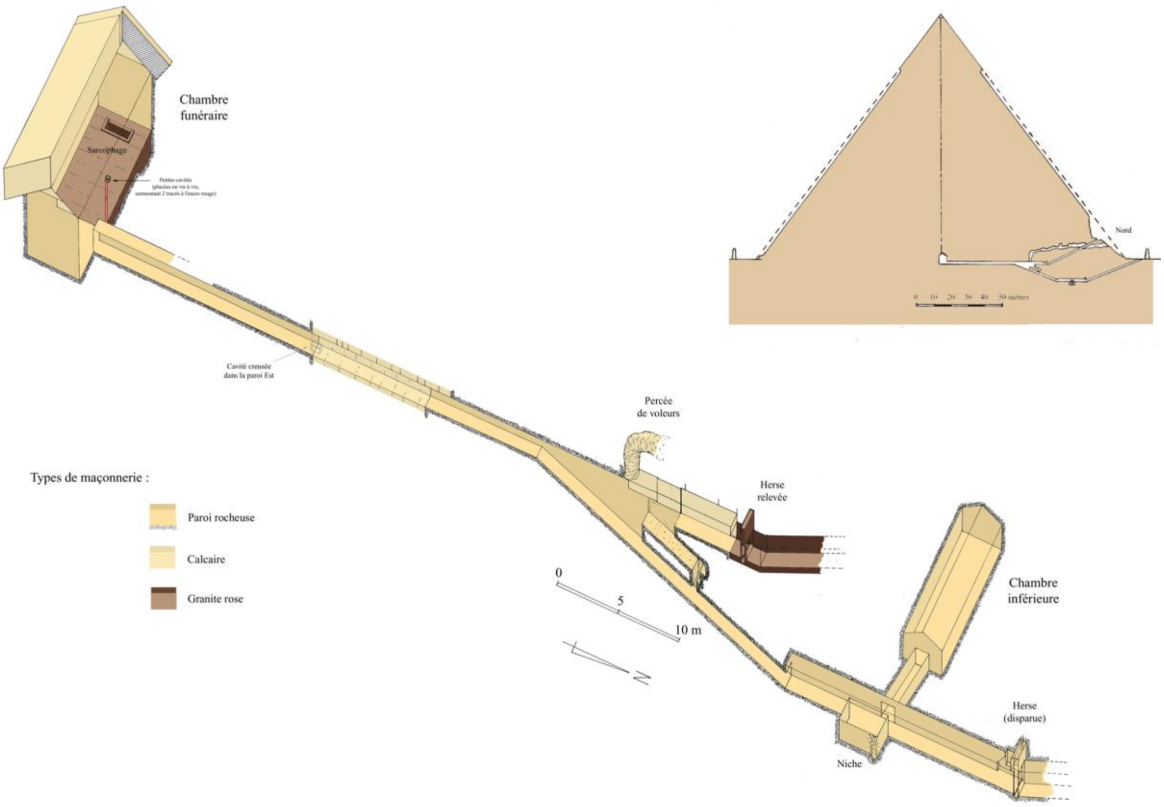
Narrow blue: extrapolation of the foundation
Green: Estimated position of the counterweight trench
Red: the Royal Causeway of Khafre.
There should therefore be some clue to confirm the presence of a trench under the pyramid of Khafre. This pyramid having literally been constructed in a quarry, the bedrock has been retained within the perimeter of its base, being as high as 7 to 10 metres in height according in some zones. Along the north-south axis, the bedrock must extend beyond the level of the base (level 70) by about 8 m.

The funeral chamber of Khafre was openly excavated into the bedrock and was then covered with Tura limestone beams laid as rafters. The horizontal corridor leading to this funeral chamber was also excavated and its floor is therefore located about ten metres from a level flush with the bedrock at this position.

In the green area on the plan above, there must be a constructional anomaly:
The horizontal corridor could not have been excavated but must have been constructed.

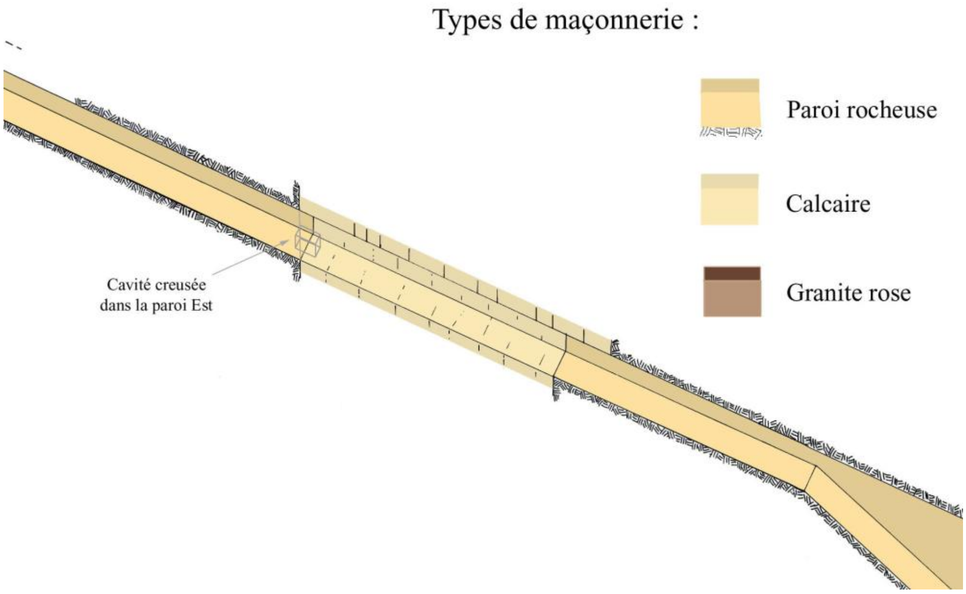



Section and plan of funeral apartments of Khafre. The horizontal corridor leading to the funeral chamber contains an anomaly: part of it is constructed and not excavated.




And this stone-built part in a trench is exactly where it ought to be.

Stonework drawn in more detail.




Extract from Wikipedia*: The pyramid of Khafre

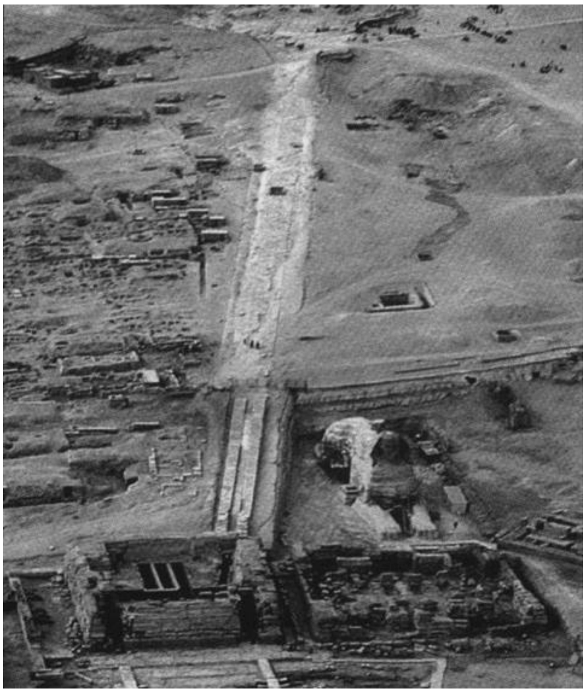
The upper level

*...This is stone-built in an openly excavated trench over a length of eleven metres then went completely underground for its greater part. This corridor, 1.78 metres high, leads straight to the funeral chamber.*

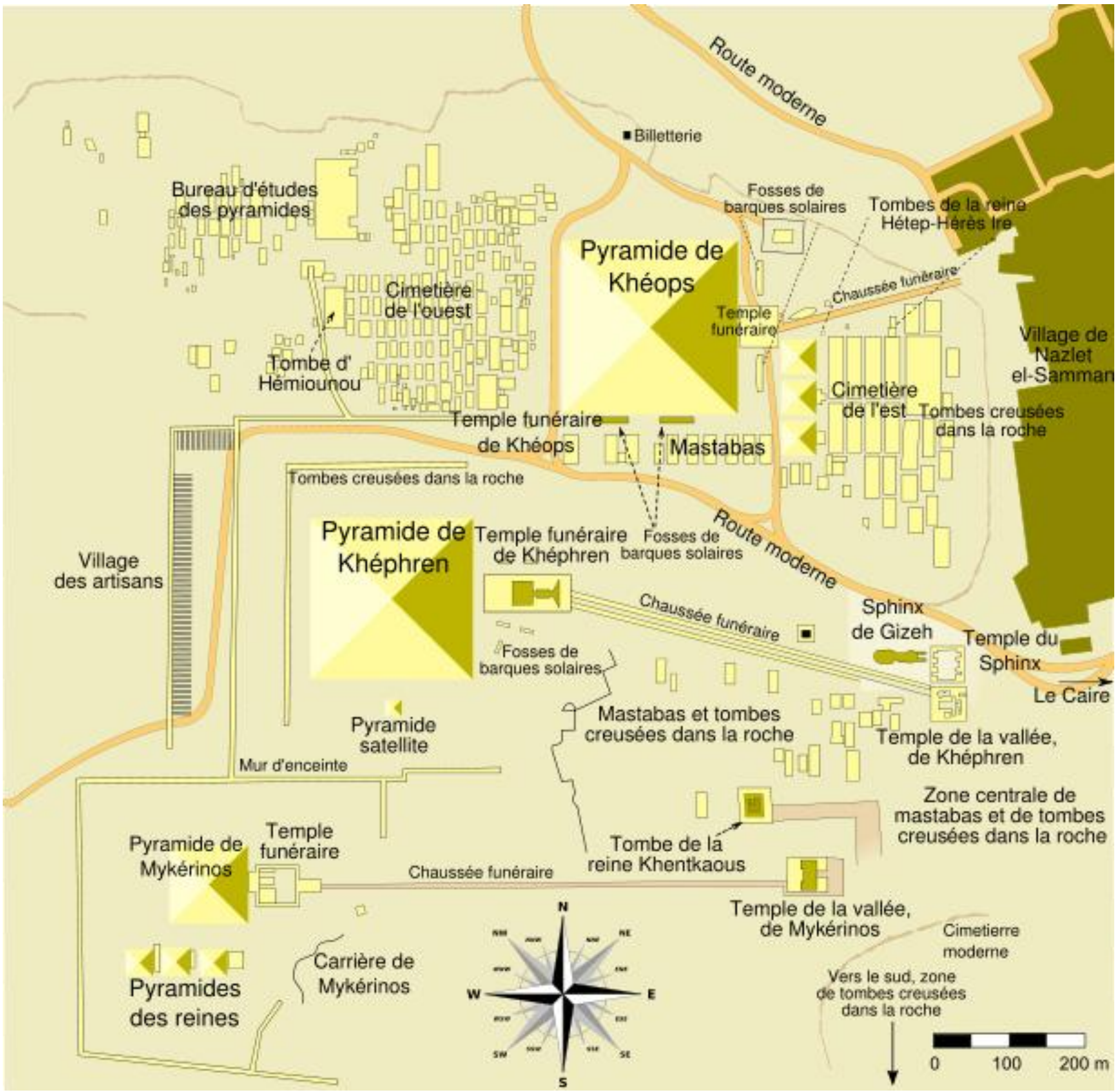
[* NdT: English translation of the French Wikipedia pages]

The presence of a ditch that could have been used for a counterweight along the extrapolation and upper part of the Royal Causeway of Khafre is thus confirmed.

Comparison of the three Royal Causeways on the Giza Plateau.

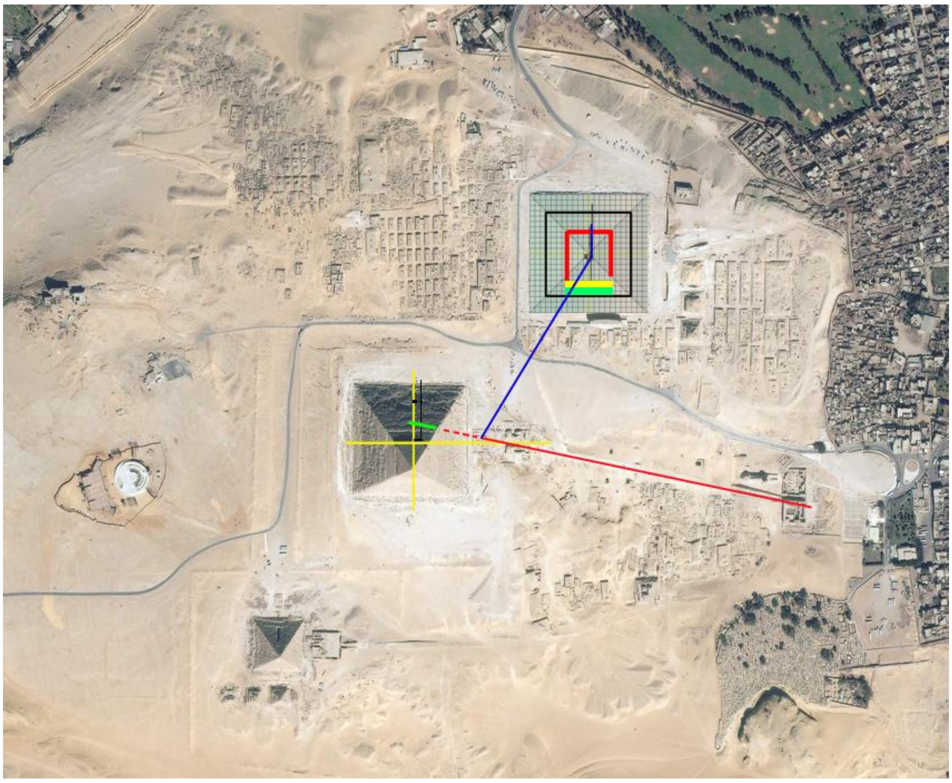


The Causeway of Khafre has wide lateral foundations.
Comparison with the foundations of the two other pyramids shows that the other two Royal Causeways were not constructed on foundations extending laterally beyond the edges of the causeways themselves. The walls rest directly on the ground.
The Royal Causeway of Khafre was laid on a foundation that existed at the time of construction.




As we have seen, towards the 14th year of Khufu's reign, all the components making up the King's Chamber and discharge chambers were stored at the port. With the pyramid having reached level +43 m, the base of the King's Chamber, all these components were then transferred in the first phase to the new storage area on this level by using two independent counterweights.

Each monolith had to be dragged twice in the course of a single campaign. First they were dragged onto the first ramp using the counterweight moving in the trench cut into the bedrock, then they were dragged for a second time onto the second ramp using the counterweight moving in the Great Gallery. When transferring from one ramp to the other, the sled was rotated through about 80° to position it in the new direction of travel. As soon as the beam had been handed over to the second counterweight, the first counterweight was immediately reset to drag a new beam waiting at the foot of the first ramp.



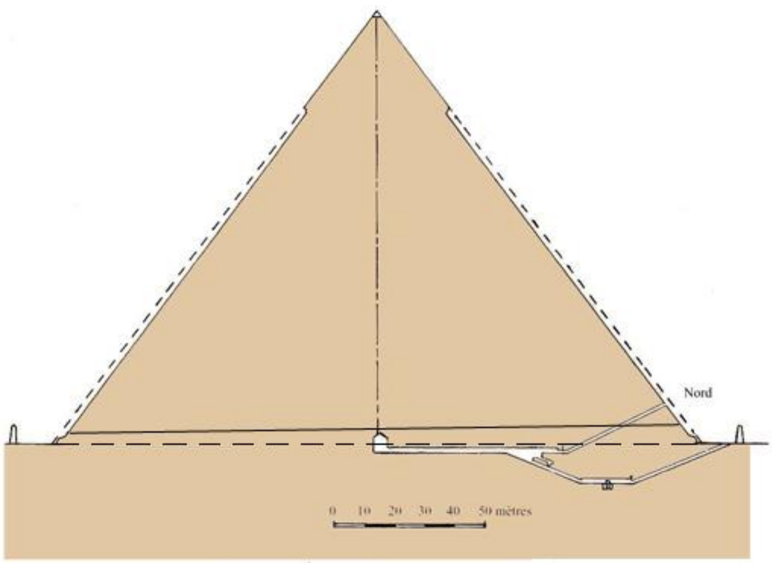
The beams were dragged along the red axis and then the blue axis. The shortest possible route.

Starting from a higher level on the Giza Plateau (at level 73 instead of level 67, as assumed until now), the ramp of Khufu, with a 9.4% slope, slightly steeper than the first ramp leaving the port, was shorter and therefore not so bulky. The pyramid of Khufu is located at level 60 and its first 13 metres could be built using a ramp descending to the construction level. When the exterior ramp started to rise, it only needed to make up a shortfall in height of 30 m. With a slope of 9.4%, it was only 320 m long instead of 425 m.

**Influence of the trench on the interior architecture of the pyramid of Khafre**

The presence on the Giza Plateau of the trench used for the counterweight for the ramp linking the port to the exterior ramp of the Khufu construction site had a major influence on plans for the funeral apartments in the pyramid of Khafre.

If there had not been a trench within the footprint of the pyramid, the architects and engineers would have designed a different layout.



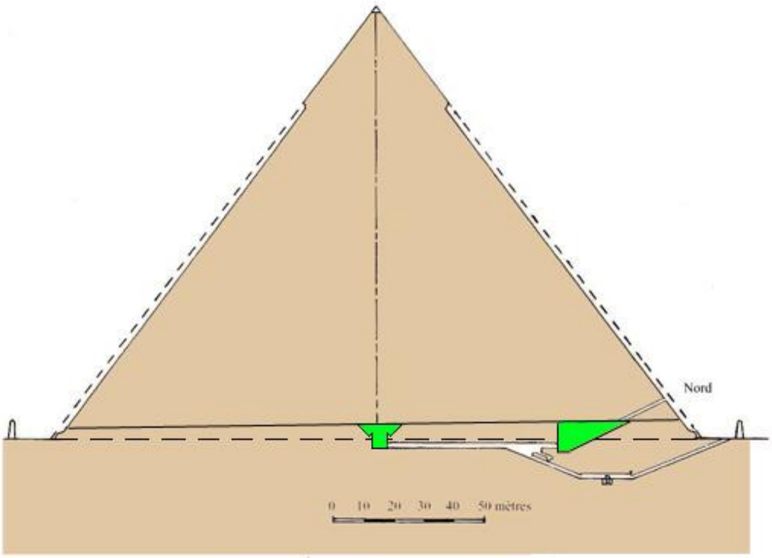

Section north-south:

It can be seen that the level of the rocky plateau (solid line), which was left intact, is several metres above the level at the bottom of the faces (dotted line) following a slope with its lowest point to the south at about +4 m above this base and its highest point, at about +8 m, to the north. The horizontal corridor therefore had to be excavated out of the bedrock over its entire length, as its ceiling was already below the theoretical 0 level, therefore at least 6 or 7 m below the natural level of the bedrock.

The Egyptians opted for this type of funereal architecture when they chose to install these structures at a relatively shallow depth below the bedrock surface. The chamber was then constructed in an excavated ditch and the descending passage was partly built in a purpose-excavated trench.

Unlike the pyramid of Khufu where the King’s Chamber was only available after more than 17 years' work, and with a view to having all the funeral chambers available, the designers of the pyramid of Khafre chose simplicity by grouping everything at the base, under the pyramid.

This option also brings to mind the Red Pyramid of Dahshur where, although the funeral apartments were constructed directly on the ground and not excavated, the choice had been made to group everything at the base and in the centre of the pyramid, again in order to have them available very early in the construction plan.




In the section shown above, we see that the funeral chamber was constructed in a, openly excavated ditch (in green, centre) before being covered by a roof made of limestone beams laid as rafters.

The upper descending corridor was “constructed”, first for the lower part in a trench excavated in the bedrock (in green, right), then into the mass of the pyramid itself.

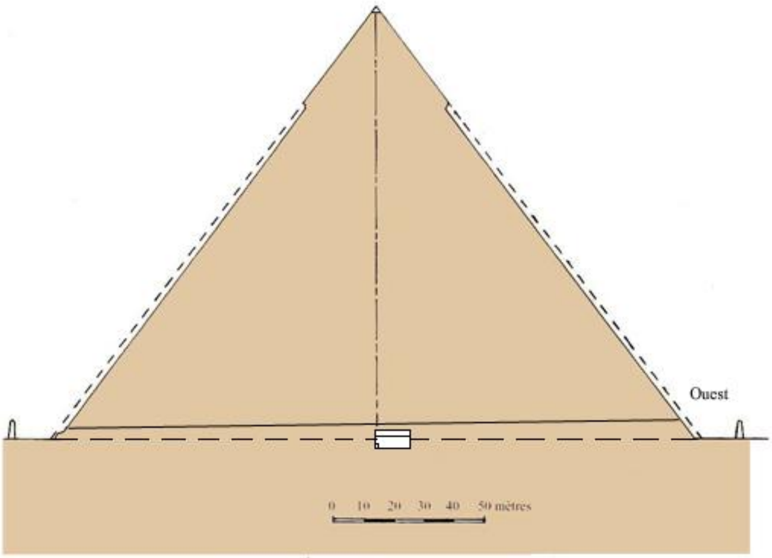
The lower descending corridor was excavated in a north-south direction, from top to bottom, using the normal technique of the time.

The horizontal corridor serving the lower chamber was then excavated in continuation.

No additional trench was therefore necessary to dig the upper horizontal corridor, fifty metres long, since the trench to the right and the ditch to the left were quite adequate to enable workers to tunnel from these two voids in order to meet in the middle.

Finally, the ascending corridor linking the lower horizontal corridor to the upper horizontal corridor leading to the funeral chamber was also excavated by tunneling, but in this case a problem arises: the Egyptians did not dig ascending corridors, always tunneling downwards. They therefore excavated it from the upper horizontal corridor.

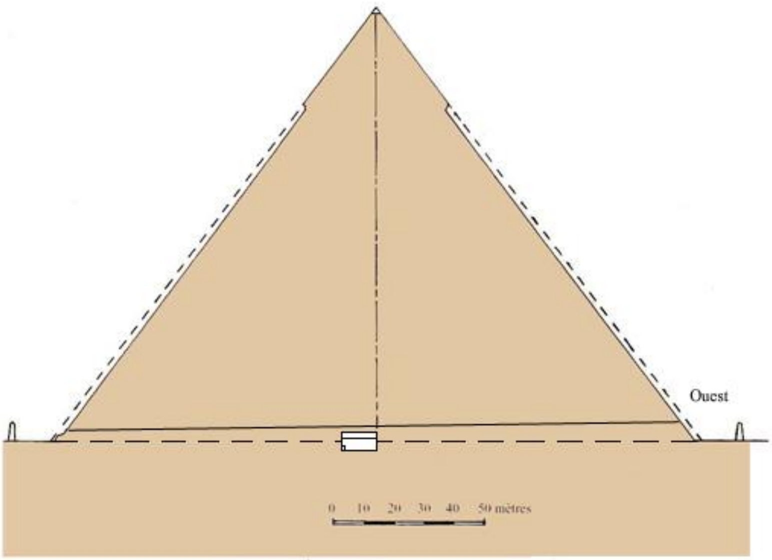
Normally, nothing would have prevented the Egyptians from aligning these corridors north-south, but a detail forced them to change their orientation.



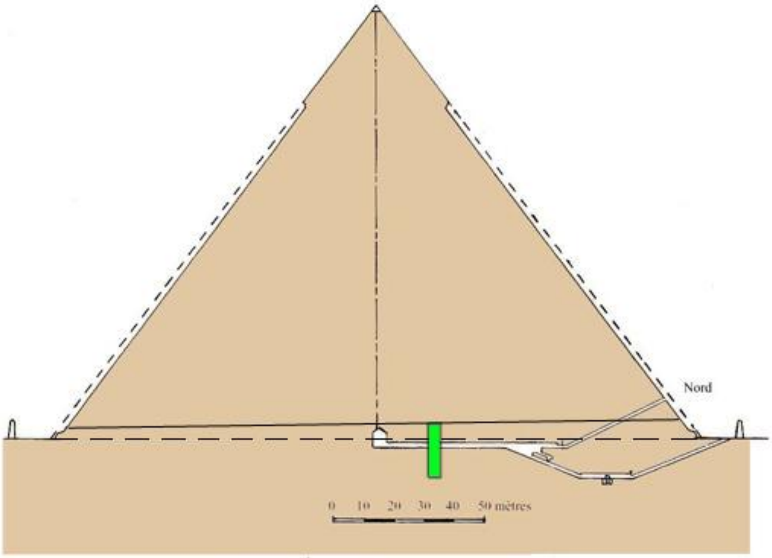

Section east-west:

The slope is similar from west to east. In reality, the bedrock that served as the construction surface had its highest point in the north-west corner and its lowest point in the south-east corner, with the plane of the slope following the diagonal joining these two corners. The horizontal corridor should have been excavated north-south, as in the majority of pyramids, an exception being the pyramid of Khufu where the axis was offset by 13 cubits (6.84 m) to the east, where the need to locate the Great Gallery, for technical reasons (counterweights), had led to this deviation.

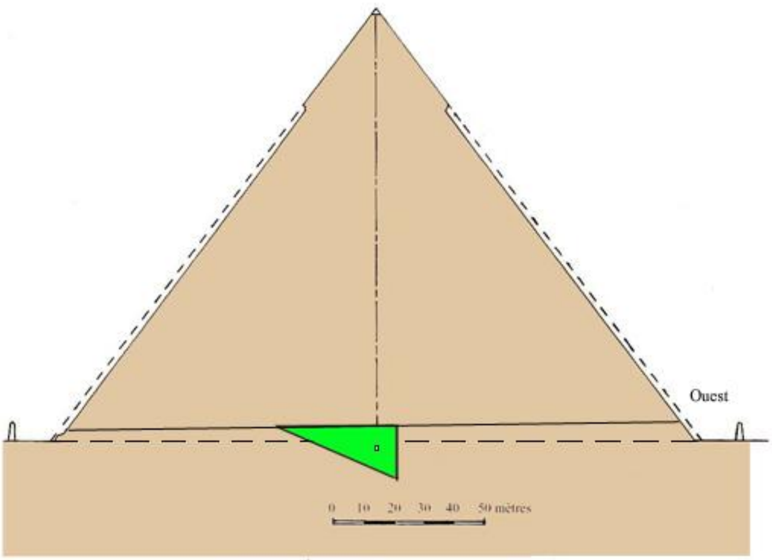
The larger part of the funeral chamber would then have been sited to the west of the north-south axis.



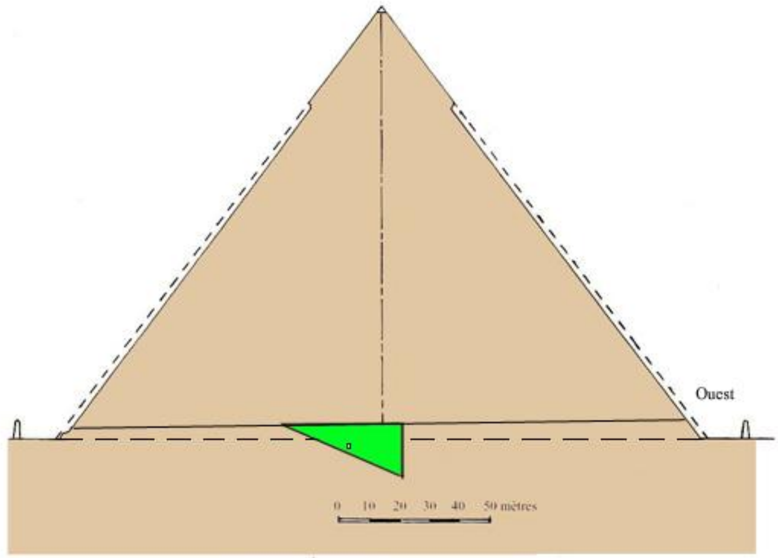

In reality, the horizontal corridor was offset by 23 cubits (12.04 m) to the east; this offset is linked to the presence of the trench and enabled the trench's position on the plateau to be determined quite precisely.




The trench, shown in green on the diagram, intersects the north-south axis perpendicularly and its position is established by the “constructed”, or stone-built, section between the two “excavated” parts of this corridor.

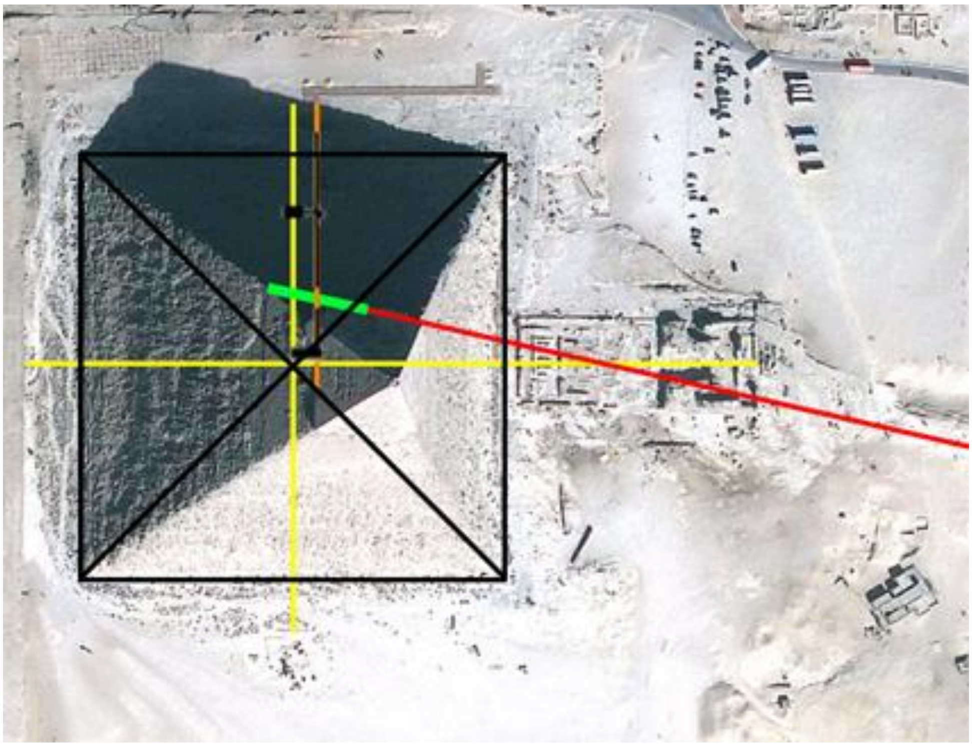



If the corridor had been positioned in the north-south axis, it would have crossed the trench where it was very deep, requiring a fairly large foundation block to be recreated, a “prop” about ten metres high, in order to find support on the rock.




The designers considered it preferable to run the trench as close as possible to the bedrock in order to reduce the underpinning requirement as far as possible; to do this, they offset the corridor 23 cubits to the east. In addition, the trench certainly having been filled in quickly towards the end of the construction of the pyramid of Khufu, it was not necessary to completely excavate it if it was not in line with the future upper horizontal corridor.

The “stone-built” section and the deviation of this corridor thus provide a fairly clear indication of the position of the counterweight trench on the Plateau, shown in green on the plan below (the ramp alignment is shown by the red line).



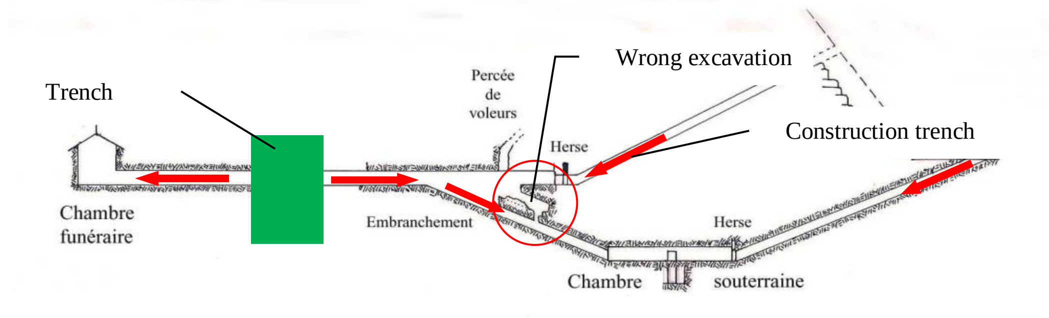
Finally, the presence of this trench also had an influence on the method of boring out the corridors, as the engineers were able to attack the site on four different fronts:

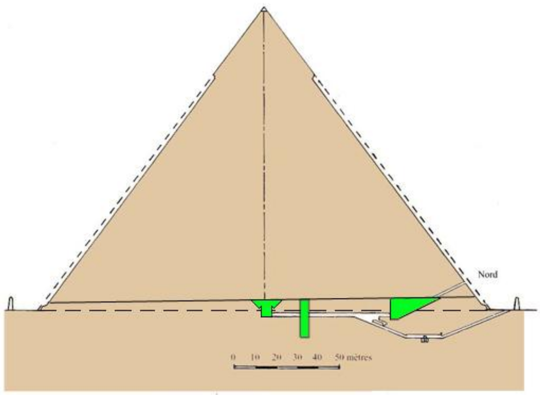
- a first front from the lower north entrance by digging the lower descending corridor,
- a second front by digging the construction trench for the lower half of the second upper descending corridor in the bedrock, to arrive at the upper entrance,
- a third front from the counterweight trench piercing towards the north from the upper horizontal corridor,
- a fourth front from the same trench boring towards the south and the funeral chamber from the upper horizontal corridor.

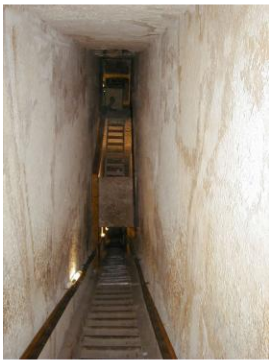
Once all these tunnelling operations were finished, the “masonry” part of the upper horizontal corridor was built. The funeral apartments could thus be constructed very quickly.

This provides answers to two questions:

- the ascending corridor linking the lower horizontal corridor to the upper horizontal corridor could have been excavated downwards by engineers working from south towards the north in the upper horizontal corridor (the third working front);
- these same engineers must have made a design mistake in digging this descending passage; it seems that started digging too far to the north. Quickly noticing this error, they apparently started a new one slightly more to the south. The abandoned tunnel was apparently filled in using carefully laid stonework.



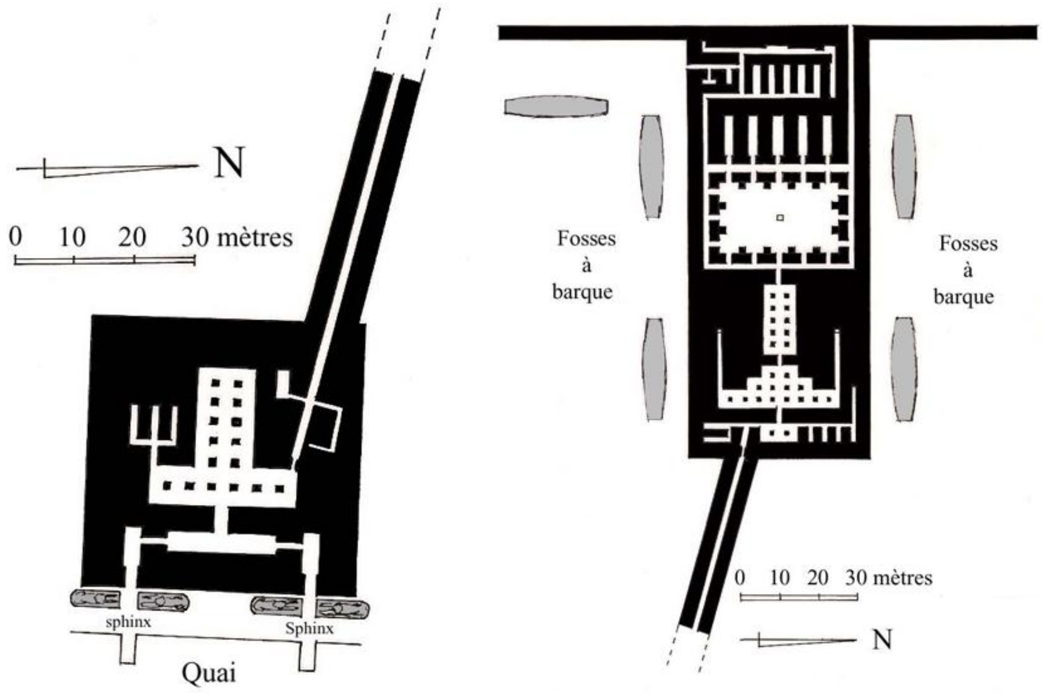
On the left: either side of the existing trench, we see the ditch excavated to create the funeral chamber and the trench excavated to construct the upper descending corridor. By analysing this section, it is clear that there was no reason to dig a new trench cutting through the horizontal corridor; on the contrary, the architects adapted their approach to this existing constraint.
In the centre: the ascending corridor seen from the upper horizontal corridor.
On the right: the same corridor seen from the funeral chamber: the corridor crosses the trench where we see the second and third lamps.

## Analysis of the entrance to the funeral temples

Entry of the Royal Causeway of Khafre into the Low (left) and High (right) Temples of Khafre.

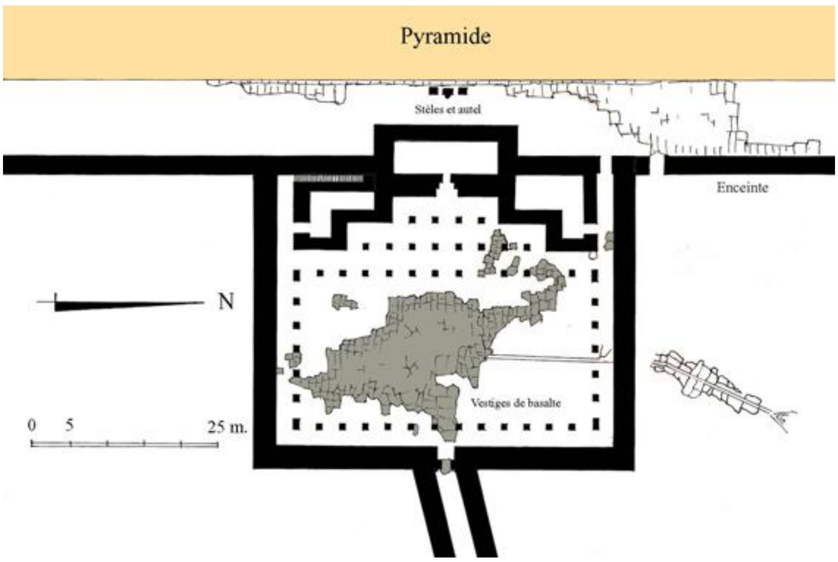
It does not enter the temples in a logical manner but had to be adapted to an existing situation linked to the presence of the first ramp for Khufu's construction site, the ramp linking the port to the bottom of the exterior ramp. It does not enter along the centre-lines of the temples but to the sides of the faces.

In addition, the architecture is solid and heavy, the void/solid ratio distinctly favouring solid. We could qualify it as "solid" architecture.



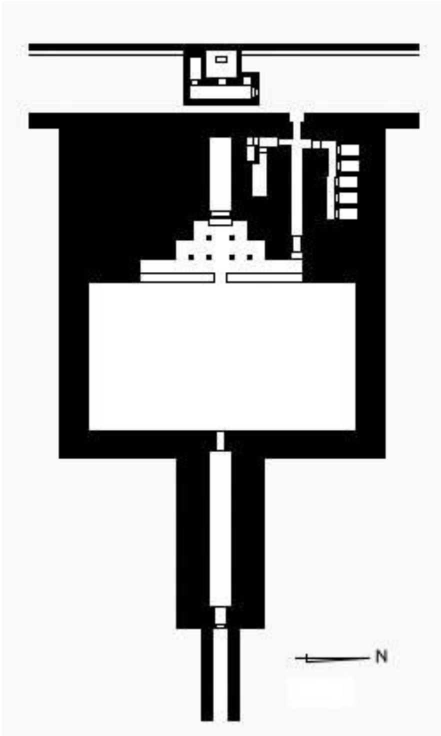

Entrance to the High Temple of Khufu: although the Royal Causeway is at an angle, it joins the High Temple on the (west-east) axis aligning it with the pyramid.

The interior architecture is very airy: this is "void" architecture and pre-dates the Temples of Khafre.

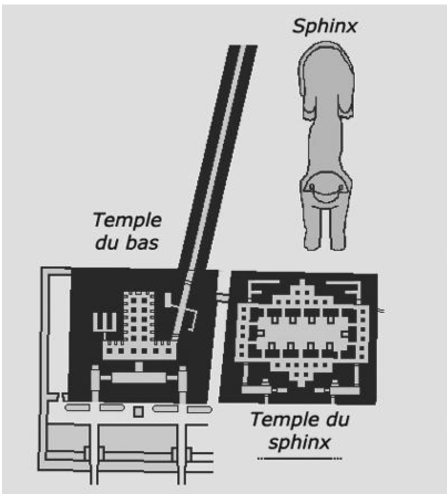


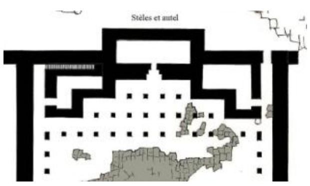
Entrance to the High Temple of Menkaure (or Mykerinos): the Royal Causeway is straight and enters the High Temple perpendicularly, in line with the (east-west) axis between it and the pyramid.

The architecture is solid and heavy: this is “solid” architecture, as seen in the Temples of Khafre, showing it was built after them.



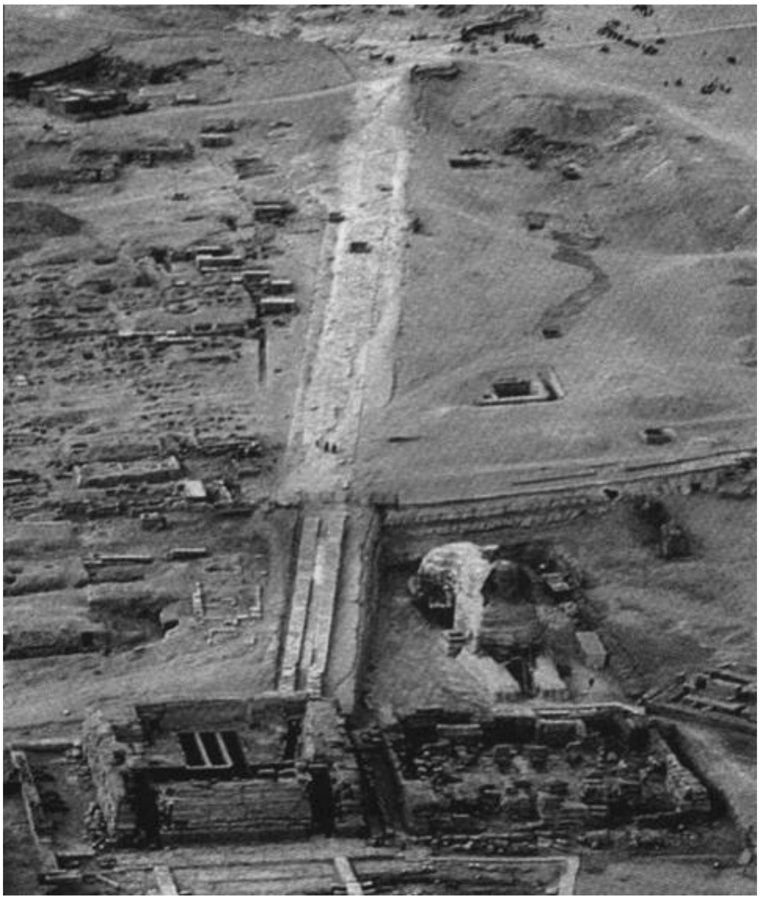

Finally, the Temple of the Sphinx and the Low Temple of Khafre. From the above observations, we can clearly see that the Temple of the Sphinx was constructed before that of Khafre; the Temple of the Sphinx has the airy architecture of the High Temple of Khufu (below).

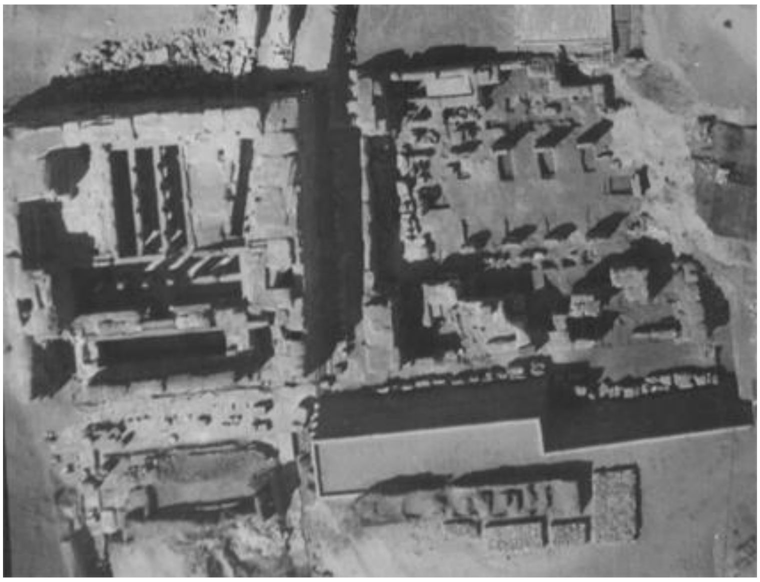


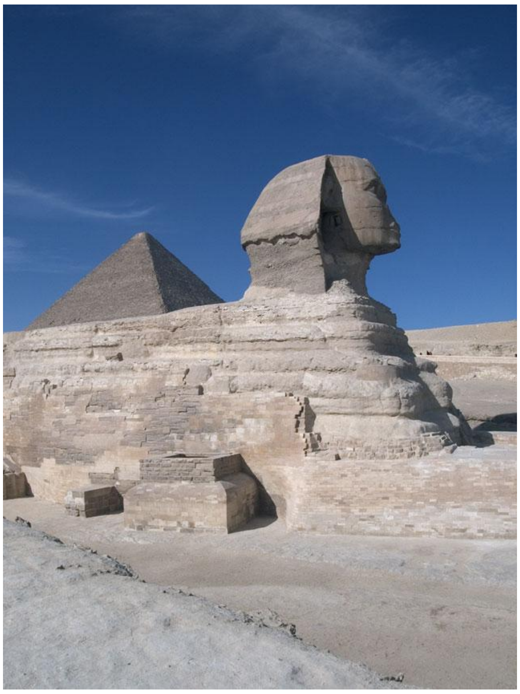
On the other hand, we note that the south wall of the Temple of the Sphinx is at an angle, indicating modification to the existing ramp. Afterwards, as the south wall of the Temple of the Sphinx already existed, Khufu's architects built his Low Temple next to it by constructing its north wall parallel to the south wall of the Temple of the Sphinx; thus they stand close together to be in harmony.

Unless Khafre wanted to reclaim it all for himself.



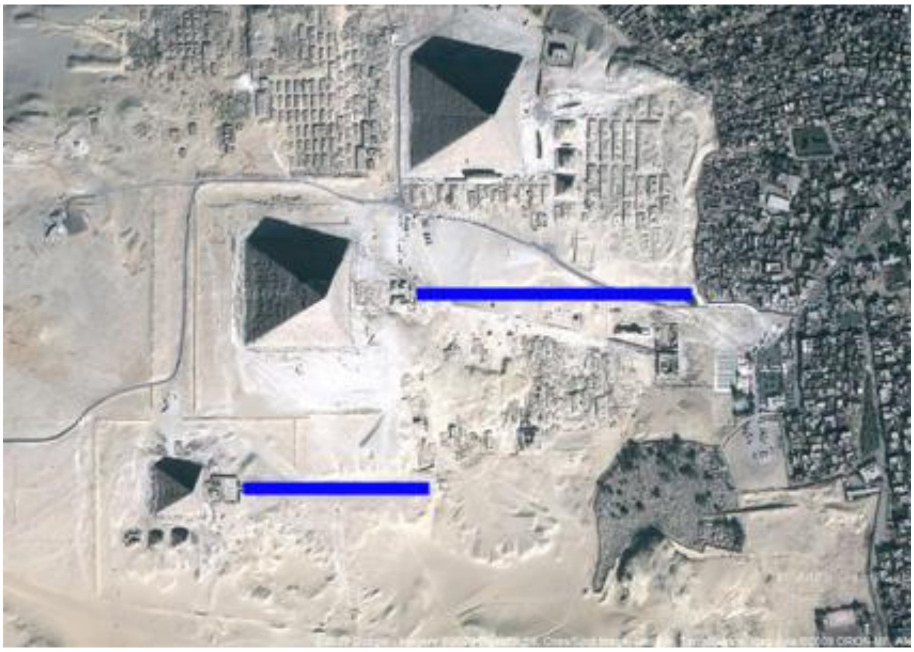


**The Sphinx represents King Khufu**



The Sphinx carrying the pyramid of Khufu as the inhabitants of Memphis would have seen it.

If Khufu's ramp in the foundations of the Royal Causeway of Khafre and the Sphinx had not existed when the pyramid of Khafre was constructed, topographers would certainly have built this causeway as an extension of the west-east axis of his pyramid, as those who built the Royal Causeway of Menkaure would do later. As for the Royal Causeway of Khufu, it was adapted to quite different terrain, marked by a cliff to the east; a depression in this to the north-east was used to lay out its location in order to link the high Temple to the Low Temple and the Nile valley.

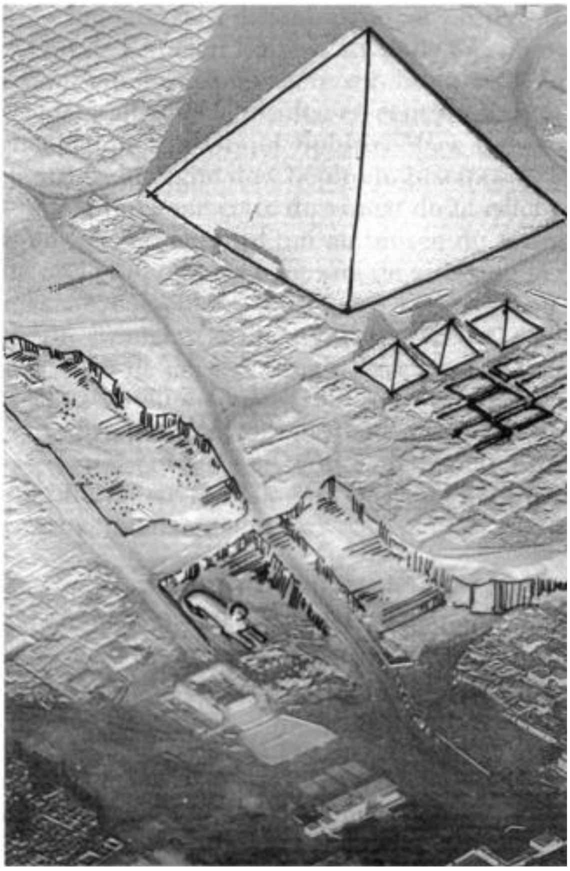


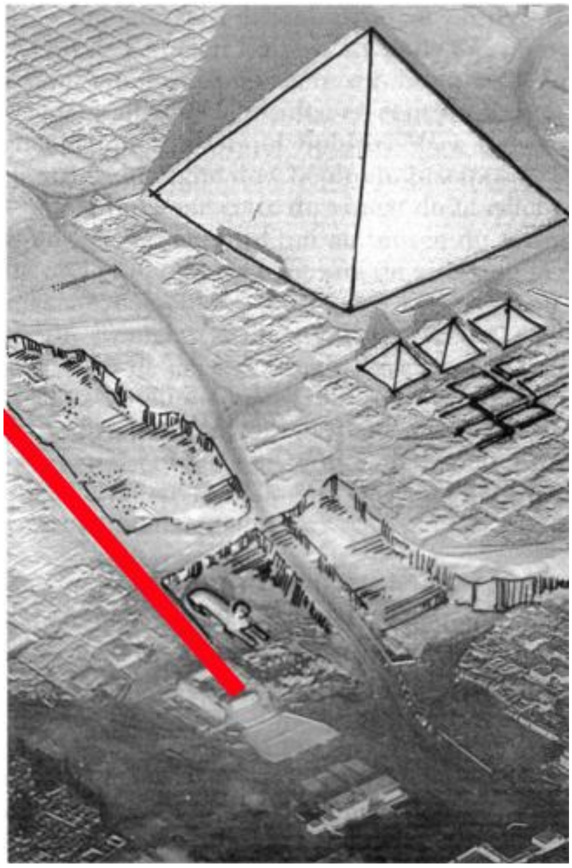
If this had been the case, the Sphinx would have been located to the left of the Royal Causeway (looking from the east) and not to the right as we see today.

Here we quote a few lines by Professor Rainer Stadelmann taken from the presentation on the Sphinx given at the *Académie des Arts et Belles Lettres* in 1999:

"Animal force appears to be tamed by the human spirit of the king, and the image now serves as a divine, majestic and calm hypostasis. This extraordinary intellectual metamorphosis is undoubtedly more in keeping with the legacy of Khufu, a driver of all the innovations, than the reign of Khafre who, without wishing to diminish his celebrity, imitated his father's works from all points of view. Even his famous statue is of a type already invented by his predecessor, Khufu, as shown by a fragment now kept at the Boston Museum of Fine Art."

Professor Stadelmann accompanied his text with an aerial photograph (the wrong way round in the original text) of the site at Giza centred on the Sphinx and pyramid of Khufu. He used a pencil to highlight the principal features: the pyramid of Khufu, those of the Queens, a few mastabahs of the eastern cemetery, the Sphinx and two quarries in its immediate environment.





We can see very clearly that the south flank of these two quarries is perfectly bordered by the ramp/Royal Causeway of Khafre (in red to the right). These two quarries are also separated by a quarry ridge providing a link between this causeway and the pyramid of Khufu, the trace of a small former ramp being discernible just behind the Sphinx. The working face of the two quarries runs along the northern flank towards the pyramid and the mastabahs. A small ramp in a trench connects all the Queens' pyramids/Mastabahs along the axis of the space separating them.

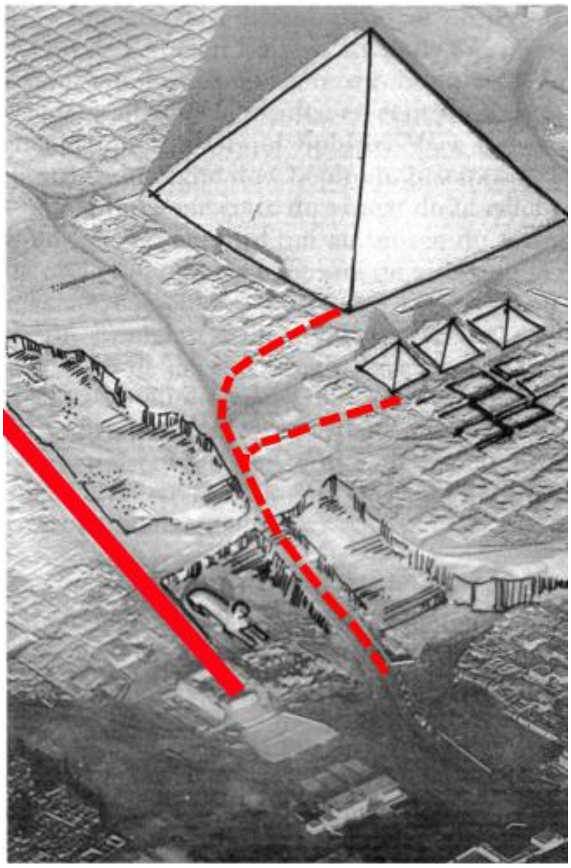
In the foreground quarry, the part on the left around the Sphinx reaches a slightly higher level than that of the Temple of the Sphinx. A service ramp was built in this quarry, cutting it into two parts; the north part is shallower and terraced on three different levels, the highest being the closest to the pyramid.

The theory supposes that the pyramid of Khufu was built using two different ramps:

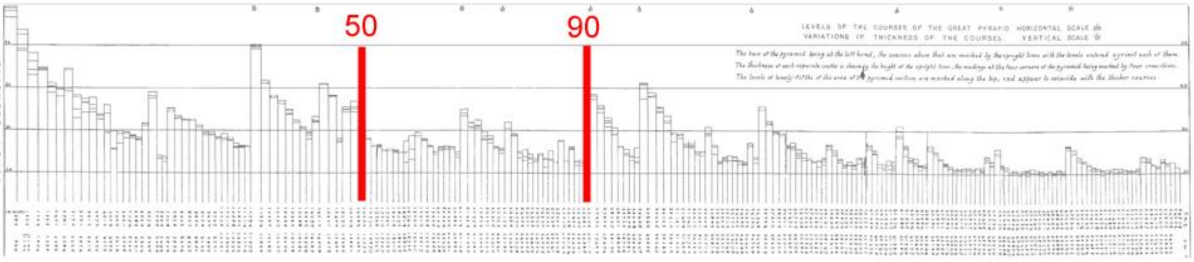
- A first, exterior ramp that served the construction site up to level +43 m while enabling continuous supply, in the monument's enclosure, by an open service ramp.
- A second, interior ramp that was subsequently used for the construction of the upper part of the pyramid. This ramp started at the south-east corner of the pyramid, close to its base (about 6 m above it).

The granite beams and blocks for walls of the King's Chamber came from the Aswan quarries, while the facing blocks and blocks for walls and certain interior structures (Queen's Chamber, Great Gallery, corridors) and Tura limestone rafter beams came from the east bank of the Nile, so a port was needed to unload them. This would have been excavated at the foot of the future Sphinx and Royal Causeway. Unloading quays are still visible at the entrance to the Low Temple of Khafre. Furthermore, surveys carried out a few years ago twenty metres to the east of these quays enabled a granite block fragment to be detected, indeed confirming the presence of a port on this site.

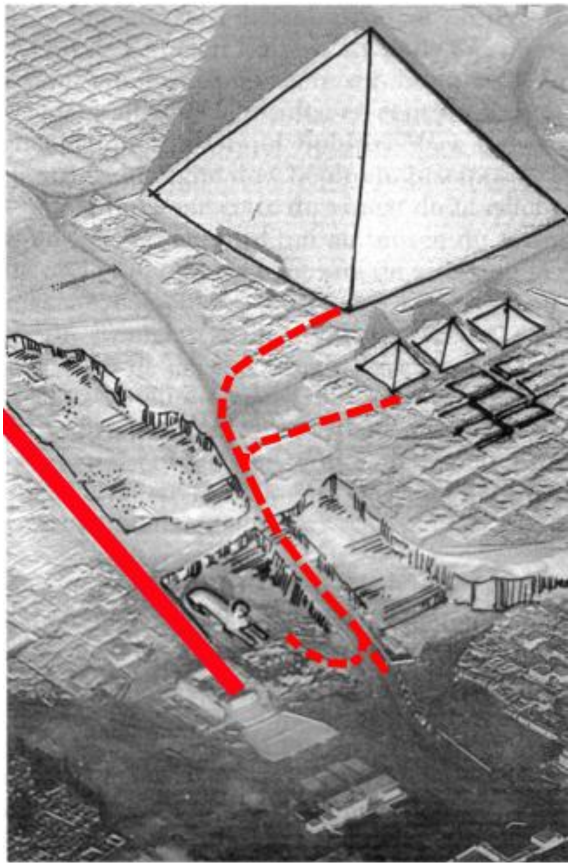
The granite blocks and heavy pieces of limestone were stored in a suitable area close to the unloading point and close to the base of the ramp/causeway, to await the moment when they would be transported and put into position, while facing blocks, which were already surfaced and numbered and therefore fragile, were taken directly to the construction site along a special route to be put in their final position, to prevent shocks due to transport as far as possible. This route left the unloading quay, climbed a service ramp built to the north of the Sphinx quarry and joined the entrance to the interior ramp by following the northern flank of the second quarry. From the beginning of the construction, the interior ramp was used to transfer facing blocks directly to their final position, ensuring the convoys were well protected. This route was also used for the Queens' pyramids and the mastabahs.

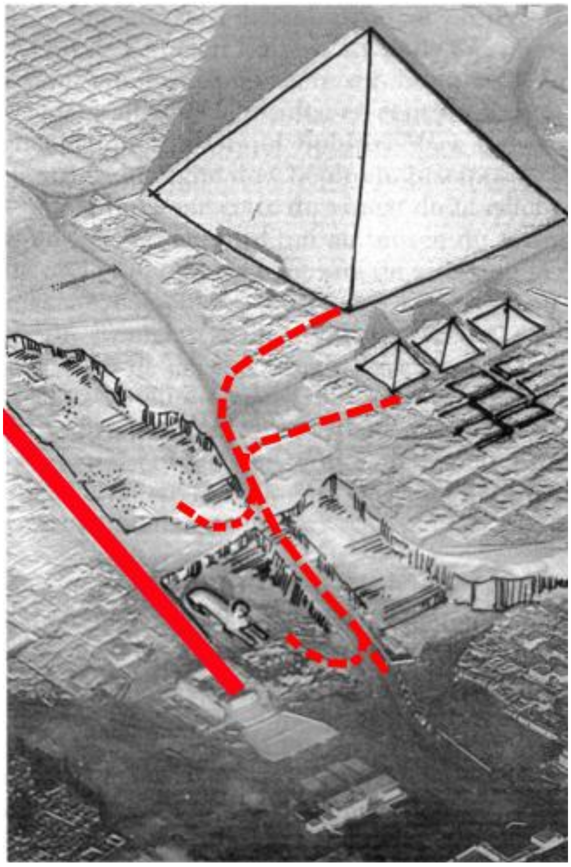


The two local quarries were exploited when construction of the King's Chamber started and the extracted blocks are located between course 50 (level +43 m) and course 90 (level +70 m). These blocks were a little smaller than average, indicating that the strata in these quarries were thinner than those in the main quarry to the south of the ramp/causeway. Measurements of course heights made by Sir Flinders Petrie show this feature well. Above course 90, the courses again became thicker and in decreasing sections, like those below course 50. Courses above course 90 were to be constructed with recycled blocks that came from dismantling the exterior ramp, thus from the south quarry.




The operating sequence for these two quarries was not laid down in absolute terms but it is obvious that the technique for attacking the bedrock in both cases allowed them to connect to the access route for the pyramid and adjoining funeral monuments. However, in the lower quarry, which is divided into two parts by a ramp, the southern part around the Sphinx seems to be older than the northern part, which is not so deep. During construction of the modern access road to the plateau, topographers used part of the old line of this ramp.





## Conclusion of this study

Extracts from the presentation by Professor Rainer Stadelmann previously cited above:

*"The southern limit of these quarries is clearly defined by the rocky escarpment on which Khafre later sited the causeway leading to his own pyramid. It is precisely because of these quarries of Khufu that Khafre's Causeway does not follow an E-W path to its temple in the valley, but deviates visibly to the south. This means that to define the path of his causeway, Khafre had to take account of an existing layout, a significant older structure that he had to go around, which required a change in the normal line of the causeway, and not the other way round, as has always been claimed. Well this object could only have been the Great Sphinx. Thus, the rectangular cavity at the centre of which the Sphinx was cut straight from the rock was certainly part of Khufu's quarries. This can be supported by comparing the stone from different courses of the Great Pyramid with various formation layers observed on the rocks that form the body of the Sphinx and the walls of the cavity. The sequence of blocks coming from the various layers is clearly identified by the type of erosion. At the start, the surface of the rock on which the Great Sphinx was cut would have to be considerably higher than the rocky plain that extends towards the south. It is likely that it was as high as the northern apron on which the tombs of the royal sons were built or at least at the same height as the mound at the extreme south that includes remnants of the quarries of Khafre and Menkaure.*

*"The entire mass of the original promontory between the current ground level in the depression of the Sphinx and the upper level of the plateau of the Great Pyramid, some 20 m in height, was extracted to supply blocks for the body of the stonework for the Great Pyramid.*

*"We therefore wonder why Khufu would have fortuitously left a mound at the southern end of his quarries, where Khafre and his craftsmen could later improvise the idea of sculpting a Sphinx, as is generally supposed. In my opinion, this idea is not convincing.*

*"Naturally, the single fact that the Great Sphinx occupies the southern limit of Khufu's quarries still does not prove that it was undoubtedly Khufu who had the idea to have it sculpted. Even so, it is unthinkable that during such a prodigious reign and in a funereal complex of such rigorous and large-scale design, the rarely equalled perfection of which makes it still one of the wonders of the world today, a rock would have been left by chance on the southern edges of the most extraordinary construction site. Moreover, the rock is located very close to the valley and is therefore visible to those living in the nearest dwellings."*

Proof that a counterweight was used in association with a ramp connecting the port to the base of the exterior ramp for the construction site of the pyramid of Khufu confirms what Professor Stadelmann postulated many years ago. The Sphinx does not represent Khafre as the photograph on the left could lead us to suppose, but Khufu without any doubt (right photograph).

## Search for clues on the Giza Plateau from 3 to 7 May 2010

The aim of this "private expedition"* was to find as many clues as possible on site to corroborate the propositions put forward in this study. It consisted of a thorough and detailed analysis of the topography and geology of the Giza Plateau, the positions of the various quarries, constructions made at the base of each pyramid, the path and construction of the Royal Causeways and finally a visit inside the pyramids of Khafre and Khufu.
The report is divided into 4 parts:

1. The Royal Causeways of Khufu and Menkaure
2. The Royal Causeway of Khafre built on a ramp of Khufu's construction project
3. Special geological features leading to the positioning of the Sphinx
4. The likely position of the entrance to the interior ramp of the pyramid of Khufu

* Before the departure for Cairo, the field study programme was prepared on the basis of the only possibilities available, namely buying tickets to enter and visit the site under ordinary tourist conditions.

### 1- The Royal Causeways of Khufu and Menkaure

The section of the Royal Causeway of Khufu from the High Temple as far as the eastern edge of the plateau was followed. The High Temple is sited straddling the east-west axis and its entrance is in the middle of its east face. Although making an angle of twenty degrees relative to the east-west axis, the causeway is clearly connected to the entrance of the Temple.

Measured in various places, its width is about 10.5 m, equivalent to 20 cubits. It gets slightly narrower (18 cubits) directly above a tunnel excavated under the causeway to make a link between the southern and northern parts of the plateau.


A large part of the Royal Causeway of Menkaure was followed from the High Temple. It departs from the Temple along its east-west alignment with the pyramid and continues along this axis for its entire length.




The causeway is constructed both sunken and on an embankment according to the topography of the terrain. Its width is constant, about 8.50 m, or 16 cubits. A central track about 4 cubits wide is clearly visible, which must correspond to the imprint of the paving for the interior corridor. The pyramid of Khufu is comparable in size to that of Khafre and studies on site indeed confirm that an average width of 20 cubits was adequate for the upper part of its Royal Causeway, with nothing to indicate that the lower part descending towards the valley should have been any different. A royal causeway 16 cubits wide was largely sufficient for the pyramid of Menkaure, smaller than its two larger neighbours.

## 2- The Royal Causeway of Khafre built on a ramp of Khufu's construction project

The Royal Causeway of Khafre was the subject of especially careful study during three dedicated visits. It was studied and followed both from the High Temple and from the Low Temple; it was also analysed from the modern road linking the entrance to the Sphinx part of the site and from the great south quarry bordering the wadi.

The description chosen for this demonstration follows the estimated route followed by granite beams and limestone rafters for the King's Chamber of Khufu.

These materials were delivered to the site's port, which was later reused for Khafre's construction site and to build this King's Low Temple.

On the left, Khafre's port; the quays are on the right.

View from the port:

In the foreground, from left to right, the Low Temple of Khafre and the Temple of the Sphinx; in centre field, the Royal Causeway and the Sphinx; in the background, the pyramids of Menkaure and Khafre.

The distance between the entrance to the Low Temple and the pyramid is more than 650 m with a change in height of 55 m, giving an average slope of 8.5%; this type of slope is well suited for use as a ramp to transport materials.

The Royal Causeway seen from the high exit of the Low Temple.

It is noteworthy that the axis of the paved passage points straight towards the central/northern zone of the pyramid. The passage is about 4 cubits wide, wall to wall, an identical width to the imprint of the paving on the Royal Causeway of Menkaure.

On the left, taken from the western edge of the Sphinx quarry, the view east down towards the departure of the Royal Causeway (a modern reconstruction) from the Low Temple. On the right, from the same position but facing west, view of the causeway towards the pyramid. Here, the floor of the causeway is cut directly into the bedrock, following the natural slope of the ground.

The measured width of the stonework in the left hand photograph is about 16 cubits, like the causeway of Menkaure, ten cubits more than the verges. In the photograph on the right, the causeway widens to a few tens of metres from this point.

The sphinx it its quarry, as seen from the Royal Causeway; the strata of the body are parallel to the causeway. In the background, the modern road follows the same slope. Only the Sphinx's head projects clearly above the natural slope of the land. The limestone of the head is different from that making up the body; it is harder and therefore less subject to erosion.

Positioned midway and over about 250 m, a slight depression under the southern half of the causeway had to be filled in with large blocks of limestone. The causeway was therefore "built" over this entire section.

On the left, view towards the Low Temple; on the right, view towards Khafre. In this whole area, the width of the causeway can be precisely measured: the central part, slightly thicker, measures 19 to 20 cubits in width and the two northern and southern verges each measure 13 cubits. Altogether it therefore measures 45 to 46 cubits (23.50 to 24 m), more than double the width of Khufu's causeway.

A single layer of blocks was sufficient to fill in this slight depression. Passers-by show the scale of the blocks. The bedrock was even excavated under the causeway afterwards.

Continuing towards the pyramid, the causeway goes right back to the bedrock, with faults crossing it in several places. At the northern edge of the causeway, the strata of an ancient quarry, excavated between the causeway and the pyramid of Khufu, can be seen. The southern edge also borders the main open quarry on the plateau. The causeway is therefore built between two quarries and its route pre-dates or is contemporary with them.

Here, the floor of the causeway has been cut directly into the bedrock, following the natural slope of the ground.

The royal Causeway enters the High Temple at an angle of about 80° in the southern section of its eastern face; the entrance is therefore not in the east-west axis. (The causeway even seems to have been deviated slightly over the final fifty metres in order to be able to reach this off-line entrance.) This part of the causeway is wider, allowing us to guess at the prior existence of a rocky promontory in which this part of the ramp would have been constructed in a trench. Later, the enormous blocks making up the walls of the Temple would have been cut from the bedrock that lay on either side and dragged to their permanent position.

The High Temple was built on a levelled natural promontory.

Once past the High Temple, one sees the base of the pyramid of Khafre; despite a certain number of joints being visible, it is clear that the enormous blocks making up the first 3 or 4 courses were cut directly into the bedrock set a few metres back from the faces and brought to the edge (second row) for make a solid and stable foundation. The pyramid is sited at level 70 and we can reasonably deduce from this that the plateau reached level 75 here before the pyramid of Khafre was built and that the entire eastern part at the base and under the High Temple had been cut back and reduced to level 70 during construction.

On the left, the central part of the eastern base of the pyramid; to the right, the north-east corner. The first four courses are “sculpted” directly into the bedrock or from blocks cut slightly set back from the face and then moved forward to the edge.

Following along the eastern face towards the north, we can see a surprising feature: beyond the slight slope to the east and to the south observed in the paving of the levelled platform surrounding the pyramid of Khafre, the paving remains horizontal over an outlying area. This area is aligned on an axis joining the south-west of the pyramid of Khufu.

This aerial photograph shows this outcrop in the direction of the pyramid of Khufu quite clearly.

On the left, beyond the slightly sloping paving, we notice a horizontal platform; as we approach we see that this is directed towards the south-eastern ridge of the pyramid of Khufu. The three holes visible about a third of the way up the pyramid start at course 50, or level +43 m. The distance from this position to the pyramid is about 300 m.

This paving is at level 70 while the pyramid of Khufu is sited at level 60. There is actually a level difference of ten metres, which means that the difference in level separating this paving at level +43 m from the pyramid of Khufu is therefore not more than 33 m. The vehicles lower down show the scale.

Retracing our steps and going back down towards the pyramid of Khufu, we can then see that this platform has also been built, as for part of the Royal Causeway of Khafre, by bringing in enormous blocks of limestone extracted slightly in front of the plateau, towards the west, and dragged into this area.

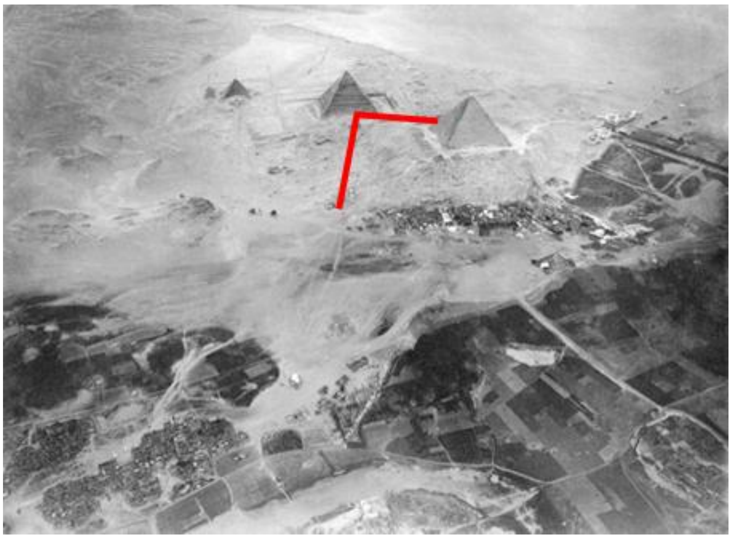
Two or three layers of large blocks making up the current platform. Once again, people show the scale of the photograph.

On the left, a large block has even been laid with its strata at right-angles, so rendering it more fragile, which the Egyptians, as experts in geology, would have avoided when building a structure, such as a ramp, that was permanent, not temporary. On the right, the vertical slab allows us to suppose that part of this platform was taken down at a specific moment without wanting to make it appear finished.

This entire platform has all the appearance of foundations pre-dating the pyramid of Khafre.

On the left, the platform seen coming from the pyramid of Khufu and on the right view from the northern side of the High Temple of Khafre. This north-east area is to be compared with the south-eastern area of the base of the pyramid of Khafre. In this part, and only a few metres from the first course, the paving sets out with a gentle slope to adopt the natural slope of the plateau towards both the south and the east; the finish is perfect.

South-eastern area: left, the paving sets out at a gentle slope towards the south; right: it does the same towards the east.



According to the theory, the exterior ramp of Khufu giving access to the construction site up to level +43 m sets out from the north-east corner of the future pyramid of Khafre and joins the pyramid in the south-east corner of its southern face.

Comparing the current Royal Causeway of Khafre with the other causeways on the plateau, it seems clear that its foundation has all the characteristics of a wide construction site ramp that would have been used to transport the heavy granite and Tura limestone beams for the King's Chamber and other monoliths for the construction. An exterior ramp setting out at level 75 from the plateau at the upper part of the future Royal Causeway of Khafre, and ending in the south-east corner of the southern face of the pyramid of Khufu, would have been about 320 m long with a fall of 28 m, or an average slope of 8.7% compared with the 8.5% slope of the present Royal Causeway of Khafre.

Current state of the Royal Causeway of Khafre with the pyramid of Khufu on the right.

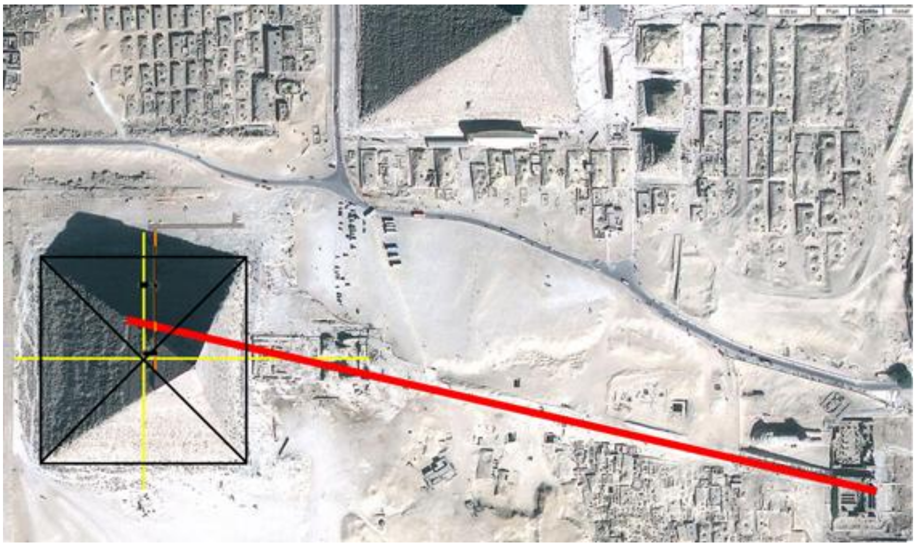
The original ramp linking the port to the base of the exterior ramp of the construction site for the pyramid of Khufu; forming an angle of 80°, this latter ramp (shown in beige at the centre of the photograph) continues on from the first ramp with a comparable slope. The total length of the two ramps is about 970 m and they rise 83 m between the level of the port and the level of the base of the King's Chamber, an average slope of 8.55%.

A ramp directly from the port to level +43 m of the pyramid of Khufu would have had a much steeper slope, of the order of 15%, which would have been unusable.

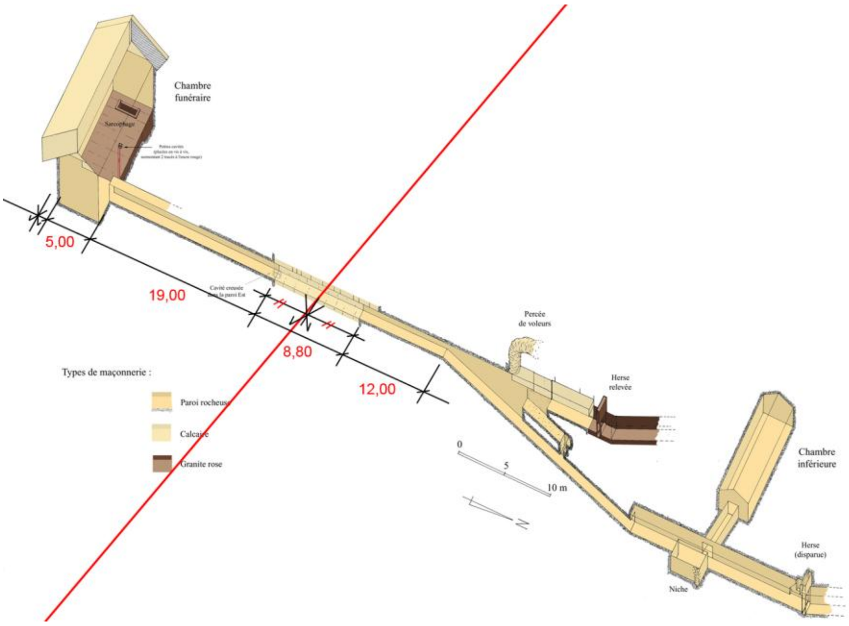
The study then considered the interior of the pyramid of Khafre and an analysis of the upper horizontal corridor. Measurements were taken to confirm the exact position of the stone-built part of this corridor, which was constructed in an open trench cut into the rocky plateau to the north of the east-west axis of the pyramid of Khafre.

When starting to study documents, it was stated:

*"The slideway for this counterweight system must have been excavated in the bedrock of the upper part of this causeway and along its extrapolation."*



The axis of the ramp under the Royal Causeway of Khafre intersects the upper horizontal corridor of the pyramid of Khafre at a little less than one third of the distance, measured from the east-west axis, between this axis and the northern base.




Measurements taken inside the pyramid show that a section of the upper horizontal corridor was stone-built, floor, walls and ceiling, over a length of 8.80 m (about 17 cubits), the axis of this stone-built part being located thirty metres north of the east-west axis of the pyramid, aligned with the extrapolation of the ramp under the causeway (red line). This section, which was stone-built in a trench at least ten metres deep, is in exactly the position assumed in the study. The stone-built length is entirely compatible with an original trench a dozen cubits wide enabling construction of a counterweight slideway comparable to the Great Gallery of Khufu; the extra cubits, distributed equally on both sides, would correspond to the lateral undermining trenches excavated in order to anchor the stone-built corridor into the bedrock, both to avoid vertical shear and to compensate for the angle of the trench relative to the corridor.

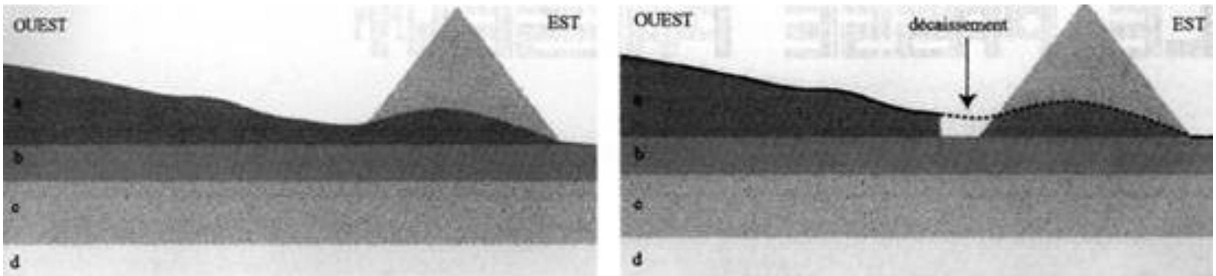
Finally, we note the presence of a parallelepipedal cavity carefully created in the stonework in the upper part of the eastern wall at the south stonework/entrance junction. This cavity could be a remnant of a temporary vertical ventilation shaft.

## 3- Special geological features leading to the position of the Sphinx

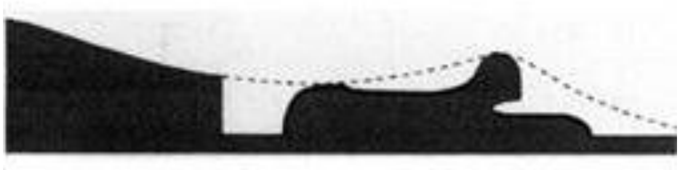
By analysing the Royal Causeway of Khufu, it appears that this was partly excavated in a trench on the eastern edge of the plateau, while that of Khafre was built partly in an existing depression in its path.

Looking at the photographs above, we can logically wonder why topographers for Khafre's construction project did not simply draw a straight line along the east-west axis of the pyramid and the High Temple to join this group to the Low Temple. Given the current topography, creating such as causeway would only have required the bedrock to be scalped occasionally, without bringing in blocks from outside. In this solution, the head of the Sphinx would have been sited to the left of the causeway and not to the right as we can see on the photographs.

One objection that could be raised would relate to the topography of this area at the time of the Fourth Dynasty. Some cite the presence of "mounds" on the plateau and in the area around the Sphinx; they suggest that the Egyptians chose sites having mounds to build their pyramids.




The pyramids of Khufu and Khafre were therefore built on two mounds that would have allowed a 40% saving in volume for each of them. Nothing on the site at Giza or in the pyramids supports such an assertion, and even less so at Maidum and Dahshur (Rhomboidal and Red) where the pyramids are built on flat ground. Taking this argument further, the Sphinx would have therefore been sculpted in a mound at the foot of the plateau.



The reality is quite different and can be seen on site less than 300 m from the Sphinx. Its head was not cut out of a mound but in a very limited rocky outcrop resulting from reduced erosion of a stratum of much harder limestone.

Left, view of the Sphinx from the road leading to the south face of the pyramid of Khufu; in the background we can see the “Hill of Crows” (Heit el-Gurob) that overlooks the wadi. Zooming in on this hill, it is noticed that several outcrops come out of it, one of which is particularly interesting.

The photograph on the left has been inversed to put it in the same direction as the Sphinx; we can see some similarities: front feet, head, body and rear thigh. The right-hand photograph shows the original position. We can easily understand that it is more tempting and easier to sculpt a head in an outcrop of this type rather than attack an entire mound. Furthermore, the reduced size of the Sphinx’s head in relation to its body certainly depends on the size of the original outcrop. If the sculptors had used a whole mound, surely they would have carved the head in proportion to the body.

A Sphinx's head could very well have been sculpted in the outcrop in the left-hand photograph.

We also notice that the bedrock surrounding the outcrop is uniformly eroded; we can therefore assume that the topography around the head of the future Sphinx was identical. So the Royal Causeway of Khafre could very well have passed to the right of this outcrop without great difficulty. The Low Temple of Khafre would have been constructed along the axis of this causeway, as for Menkaure. The sphinx would have been sculpted and excavated and its Temple would have been in the same place, but to the left of the Low Temple of Khafre.

In reality, the topographers did not have this option because they did not draw the Royal Causeway on undisturbed ground, but had to take account of the existing layout on the plateau.

In fact, they advised the architects and surveyors to make use of an old abandoned construction ramp to site the Royal Causeway of Khafre, with all that that implied for the plans for the High and Low Temples: the offsetting of the entrances from the processional corridor into these Temples. These disadvantages were minimal compared with the enormous gain from re-using an existing ramp as the foundation for the Royal Causeway.

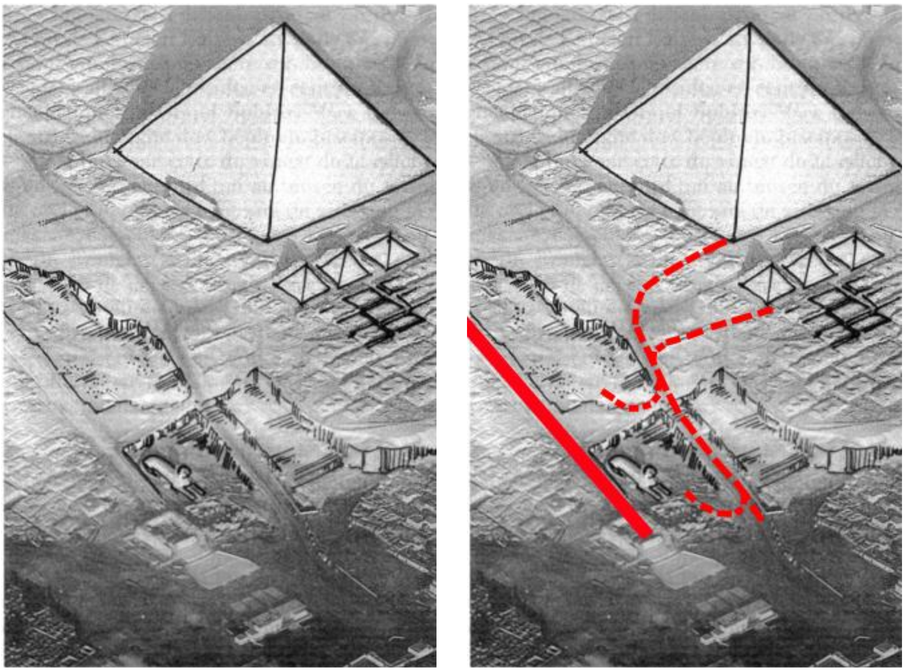
Nonetheless, one question comes to mind: why did Khufu's topographers not site the ramp leading from the port to the foot of the exterior ramp serving the pyramid to the right of the Sphinx? The problem here is totally different because the architects absolutely needed a quarry immediately to the south of the pyramid for part of its construction during the building of the King's Chamber. By running the ramp to the left of the outcrop that was going to become the head of the Sphinx, they "opened" the angle between the ramp and the pyramid and thus freed up a complete flank of the plateau, in which they could open two sizeable quarries with direct access to the construction site. The first was excavated around the Sphinx while maintaining a ridge from which it was sculpted later. The second was excavated above the first by working towards the west. A third, smaller ramp was built along the northern flank of these two quarries. In addition, this layout made the transfer from the first ramp to the second ramp easier, with regard to the rotation of the sleds loaded with heavy beams.

### 4- <u>The likely position of the entrance to the interior ramp of the pyramid of Khufu</u>

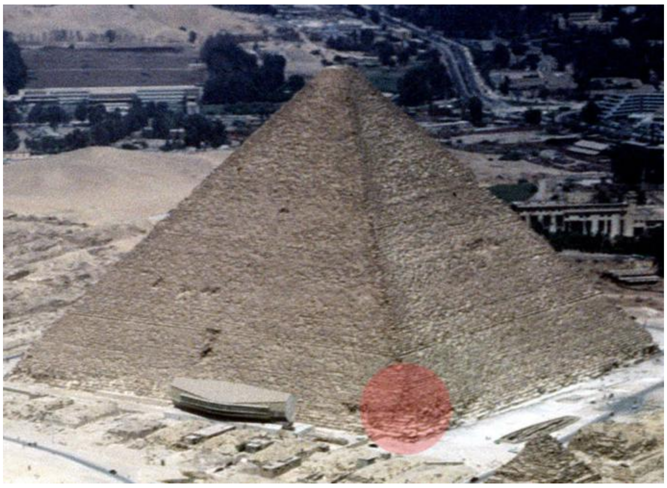
At the end of study documents, it was stated:

*"...facing blocks, which were already surfaced and numbered and therefore fragile, were taken directly to the construction site along a special route to be put in their final position, to prevent shocks due to transport as far as possible. This route left the unloading quay, climbed a service ramp built to the north of the Sphinx quarry and joined the entrance to the interior ramp by following the northern flank of the second quarry."*

The last part of the expedition to the site consisted of reconstructing the likely route of the Tura limestone blocks from their unloading quay at the port as far as the estimated entrance of the interior ramp in the south-east corner of the pyramid of Khufu. The journey was the same, in part, for the transport of the limestone blocks extracted from the two quarries previously described. On the path of this third ramp, structures were constructed over time, the last iteration being the route that links the access to the site at the Sphinx to the Giza Plateau by following the southern face of the pyramid of Khufu.



In parallel with the first ramp for the construction site of the pyramid of Khufu under the future Royal Causeway of Khafre, a third ramp joined the port and the northern quarries to the entrance to the interior ramp assumed to be located at the south-east corner of the pyramid of Khufu. The difference in level between the port and the base of the pyramid is 40 m and the route measures about 550 m, making an average slope of 7.2%.



According to the theory, the assumed entrance to the interior ramp is located in the south-east corner (red area).

Panoramic view from the esplanade in front of the Temple of the Sphinx.
In the centre of the photograph, it will be noticed that the remaining bedrock allows us to guess the slope of an old ramp used as the foundation for the modern road.
To the left and behind the Sphinx, the strata of the quarry clearly show the incline of the northern flank of the plateau to the south of the pyramid of Khufu.
On the right, the northern flank of the Sphinx quarry.


In the left background, the pyramid of Khafre and to the right the pyramid of Khufu.

On the left, a third third of the way along the journey: view of the western limit of the Sphinx quarry and to the right, the pyramid of Khufu.

Left, two thirds of the way along the journey, we see the remains of the small ramp serving the Queens' pyramids and the Royal Mastabahs. Right, the final few metres before arriving at the base of the pyramid.

Arriving in front of the southern face of the pyramid revealed a surprising anomaly. A second series of photographs was therefore taken the following day using a different camera. The lighter photographs were taken during the first visit, the darker ones during the second.

One hundred metres from the pyramid, although the research related to the south-east corner itself, a strange anomaly appeared about 25 m to the left of the corner. The arrangement of the limestone blocks cries out for attention.

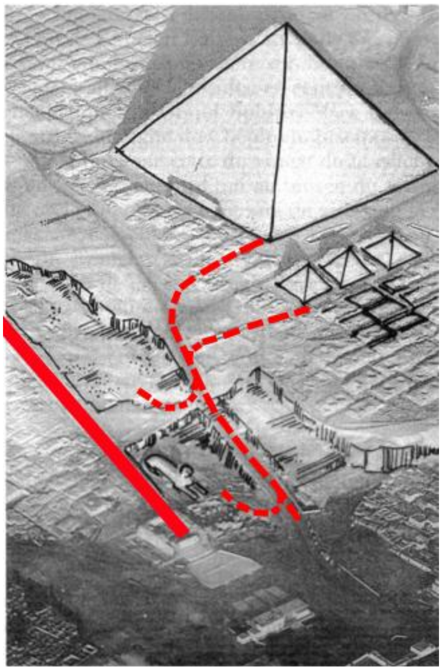
 

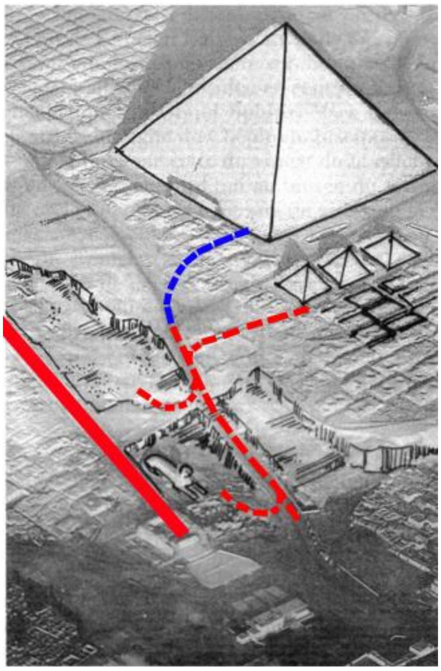
Closer to the facade, a hollowed-out can be very clearly seen, standing out from the rest.


The positions of the blocks are very curious; some parts have been sealed by rubble and cement mortar, while on each side of this area the stone-work is matched and regular.
We also found recent stone-work that came to the fore in places.

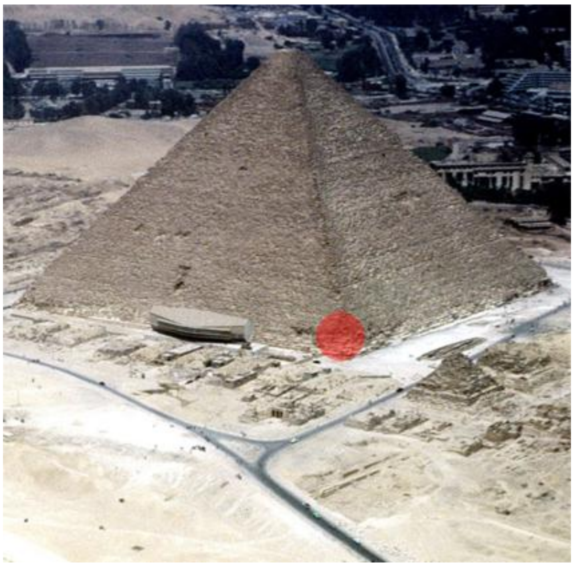

According to the theory, the interior ramp left from the south-east ridge to reach the first sled-turning area at the north-east ridge at level +20 m. Its path is parallel to the sloping face so as always to stay at the same distance from it. The interior ramp continued, following this principle in each section, each turning area determining the openings. In fact, the problem does not arise for the first section of the interior ramp because its entrance did not depend on a turning area. This could therefore be located on the south face perpendicular to the first turning area, so simplifying its construction. By projecting the axis of the opening perpendicularly to the south face, it can be seen that the entrance had to be located about 25 m from the west of the base of the south-east ridge, at exactly the place identified on the photographs above.

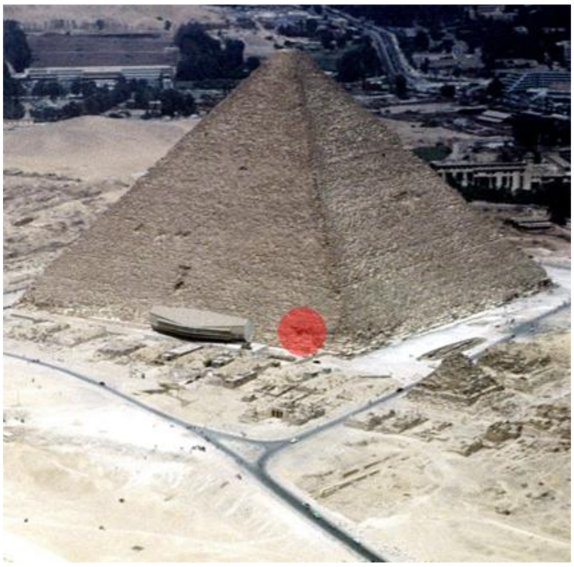
By taking the presumed path of this third ramp, and after adjusting it to take account of this anomaly in the stone-work at the foot of the southern face of the pyramid, it turns out that the new path is even more logical than the previous one.





The new access path arrives slightly higher on the plateau, so about 1 m above the level of the base of the pyramid. The small ramp constructed in continuation, to reach the level of the entrance to the interior ramp, is thus reduced, there being less difference in level.





The entrance to the interior ramp is not at the corner as indicated on the left-hand photograph, but about 25 m to the west of the corner as shown on the right-hand photograph.

It will also be noticed with interest that there are four indentations on the southern face, already mentioned above, at the level of the $50^{th}$ course (level +43 m); their purpose is currently being studied. The origin of two other indents on this face is known: the first, a little above the base and on the mid-line, is the work of Vyse, and the second, two thirds of the way up, is the exit of the south passage from the King's Chamber. The damage half-way up on the eastern face also seems curious.

**Conclusion of this "private expedition" report**

The starting point for this entire study goes back to Autumn 2009, following a comment made by an Internet user on a forum discussing the transport of granite beams from their unloading quay at the port as far as the base of the exterior ramp. This comment was asking for a clear and realistic explanation. Strangely, an aerial photograph of the Giza Plateau, taken in February 1904 by Eduard Spelterini from an aerostat, was posted by chance the day after this event by Vincent Brown on his *Talking Pyramids* blog. The angle and height from which this photograph was taken were such that the answer became obvious.

Going beyond what was expected and as fully confirmed on site with regard to ideas postulated in the first part of this document, several significant new advances have been made in the "more-than-likely historical reconstruction" of the Giza Plateau pyramid construction projects.

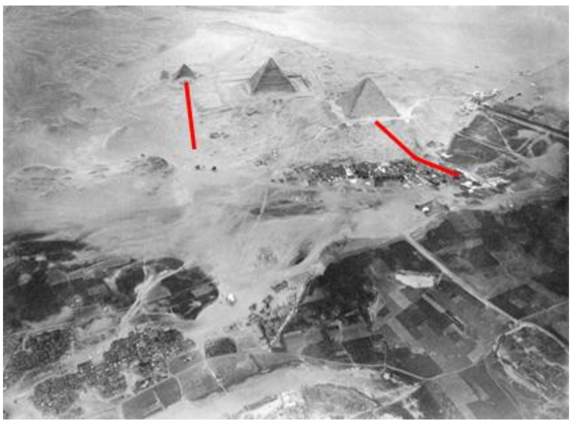
These advances concern the four parts of the on-site study:

1. The Royal Causeways of Khufu and Menkaure
2. The Royal Causeway of Khafre built on a ramp of Khufu's construction project
3. Special geological features leading to the positioning of the Sphinx
4. The likely position of the entrance to the interior ramp of the pyramid of Khufu

Taking them one at a time, these advances are:

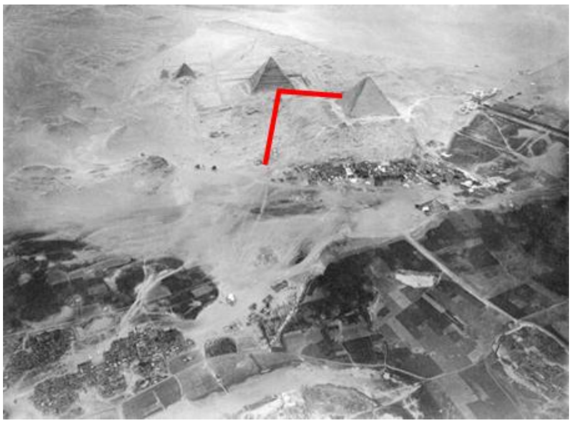
1. The Royal Causeways of Khufu and Menkaure

It seems clear that these two Royal Causeways were constructed with the one and only objective of creating the most direct and shortest possible connection between the Low Temples, which could have been sited very close beside the canal running alongside the plateau, and the High Temples, constructed at the bases of the eastern faces of the pyramids of Khufu and Menkaure. These causeways, having had no function during the construction of these pyramids and not therefore depending on them, could have been constructed in parallel with the pyramids.



2. The Royal Causeway of Khafre built on a ramp of Khufu's construction project

We can now postulate without doubt that the Royal Causeway of Khafre was built on a wide supply ramp to the site established for the construction of the pyramid of Khufu. It was part of a pair of ramps linking the port to the construction site for the pyramid of Khufu by the shortest possible route given the topography. To solve the problem of transporting heavy loads for the construction of certain structures (principally the King's Chamber), two slideways for counterweights were created at the tops of these two ramps: the first in a trench beneath the current footprint of the pyramid of Khafre, the second being the Great Gallery. This therefore confirms the uniquely technical function of the gallery, with no specific funereal function.

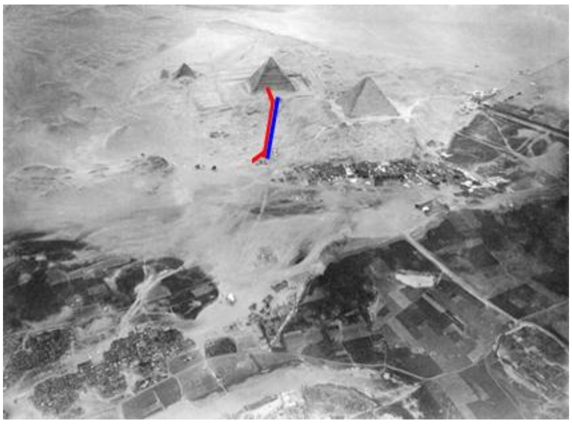


The site study enabled us to bring to light a previously unsuspected clue: remnants of the foundation for the exterior ramp for the construction of the pyramid of Khufu. The presence of enormous local limestone blocks piled up to the north-east of the pyramid of Khafre, to the right of the top of the ramp arriving from the port, on an axis aligned with the south-west of the pyramid of Khufu, enabled the exterior ramp to positioned exactly. The length and volume of this ramp were less than had been propounded in theory, showing an extraordinary degree of expertise.

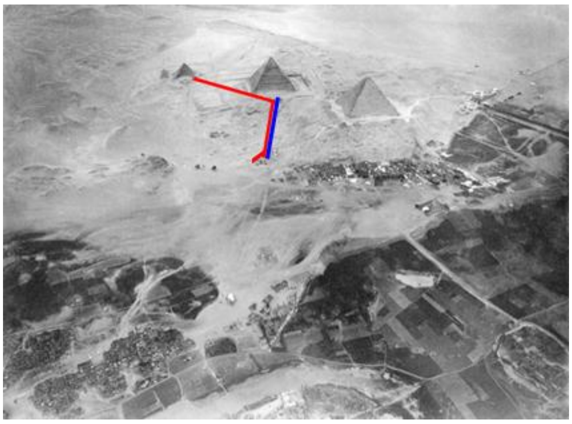
Analysis of the site would even allow the starting point of the exterior ramp of Khufu to be offset slightly to the west, in the very footprint of the future pyramid of Khafre, which supports a starting point for this ramp at level 75.

Continuing the investigation on returning from Egypt enabled an additional clue to be discovered in the microgravimetry study performed in 1986/87. In the article "*Microgravimetry probes the Great Pyramid*" published by Jacques Laskhmanan and Jacques Montluçon, members of this expedition, in the journal *GEOPHYSICS: The leading edge of exploration for January 1987*, the end of last paragraph on page 15 includes these words: "…, *we feel that the lower south-west part of the pyramid could be heavier*…." This lower south-west part of the pyramid would therefore have been strengthened so that the exterior ramp was supported in this area, exactly as the observations made on site would seem to suggest. The width of the ramp under the Royal Causeway of Khafre and the way in which it was built show that it was certainly used for the construction of the second pyramid.

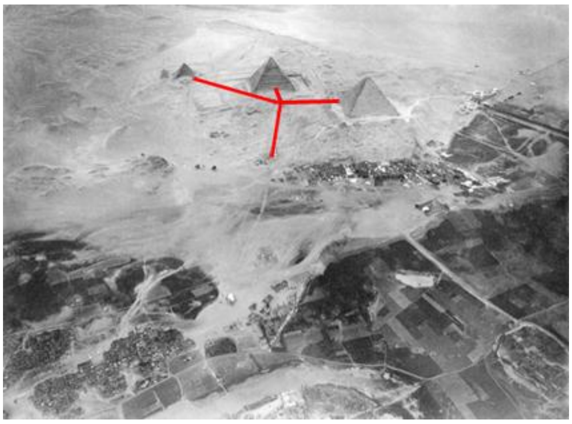
In addition, it is very likely that the Royal Causeway of this funeral complex could have been built while the ramp was being used without disrupting the construction. The width of the Royal Causeway (about 18 cubits), aligned on the ramp, left a southern verge 13 cubits wide, easily enough to transport the small Aswan granite and Tura limestone blocks for this construction project (ramp in red and Royal Causeway in blue on the photograph below). It can also be deduced that the position of the entrance for the interior ramp in the pyramid of Khafre is to be sought at the base of the eastern face, slightly to the south of the east-west axis.



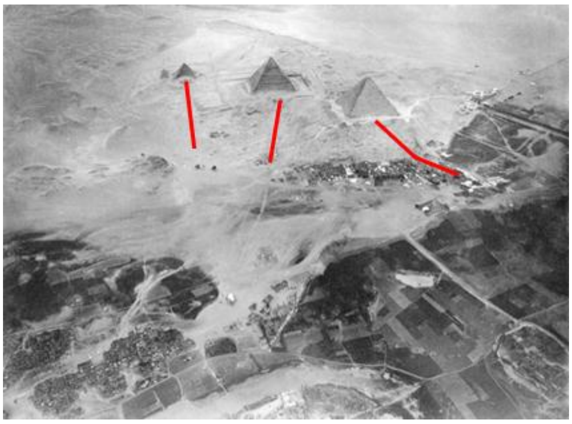
In fact, this southern part of the original ramp could also have been used to construct the pyramid of Menkaure without encroaching on the funeral area of Khafre.



Spread out on the Giza Plateau, the three pyramids are perfectly adapted to the topography. The location of Khufu's first ramp on a central axis with a natural slope of about 8.5% allowed a supply route to be established at lower cost. Equally remarkable, this location enabled this arrangement to be used for two future construction projects.



While “sticking” to the ground, topographers found a remarkable solution to the major problem represented by the transfer of granite blocks weighing up to 60 t or more from the port of delivery to the base of the King’s Chamber in the pyramid, a difference in level of 83 m, by the shortest possible route.



As a result, the Royal Causeway of Khafre could only be built on ramp 1 of Khufu’s construction project, the shortest distance between the valley and the base of the pyramid, the layout we find for Khufu and Menkaure.

3. Special geological features leading to the positioning of the Sphinx

The unexpected event of this expedition was the on-site observation, made by simple visual observation of the site, of a very important geological feature that has never been put forward regarding the Sphinx, particularly in relation to sculpture of the head. Hard limestone outcrops on the “Hill of Crows” show the original state of the ground in the Sphinx enclosure, which allows us to understand exactly why and how this enigmatic guardian of the site was created. There was no “mound” strictly speaking in this area and the size of the Sphinx’s head in relation to the body is entirely due to the original limestone outcrop.

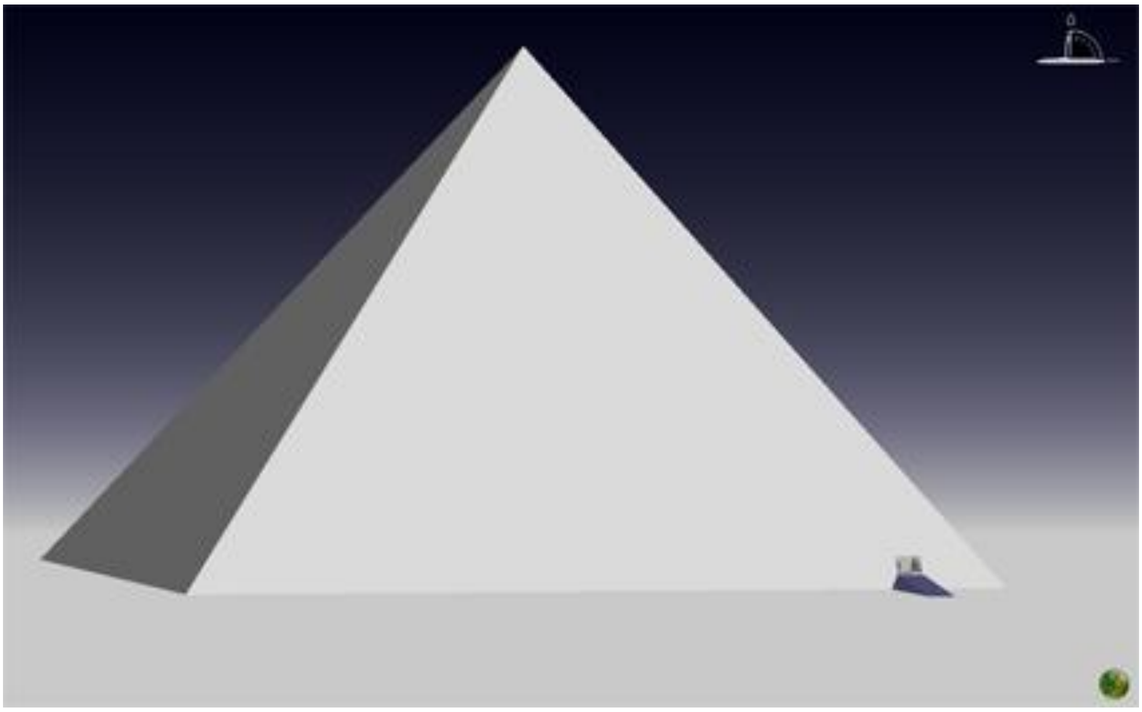
The Sphinx’s head could very well also have been sculpted in this outcrop sticking out of the “Hill of Crows” (picture inversed)

4. The likely position of the entrance to the interior ramp of the pyramid of Khufu

Here again, observation on the site enabled us to discover a very important clue supporting the theory of the interior ramp and to understand a technical reason associated with the location of the entrance for this ramp. In fact, in theory, the entrance was located at the south-east corner of the pyramid, so that the first section of the interior ramp ran parallel to the eastern face, taking account of its slope. By retracing the supposed route of Tura limestone blocks from the port as far as the entrance to the interior ramp, the closure you get to the pyramid, the more obvious it became that the entrance was sited behind a hollow associated with the theft of facing stones about 25 m from the south-east corner.

In fact, the first section did not need to run parallel to the eastern face, it could simply be perpendicular to the northern face, the opposite face, and so set off also perpendicular to the southern face. The only constraint was that its exit on the northern face should be in the same place as was defined in the theory. By drawing a line from the axis of this exit perpendicular to the southern face, it turns out that this line meets this southern face exactly at the observed hollow.

Models created since then with engineers at Dassault Systèmes are very clear.



The pyramid of Khufu was constructed from the inside as far as the top, the facing blocks made of Tura limestone having already been fashioned in their final form prior to being laid. No openings to the outside were retained during construction, except for the entrance to the interior ramp on the south face, near the south-east corner.

**About the particular rain erosion of the vertical walls of the Sphinx pit**

A theory, first put forward in the 50s and recently revived, attempts to demonstrate that the Sphinx was already present on the Giza Plateau several millennia before the construction of the Great Pyramids. This theory is based on an analysis of the rain erosion affecting the vertical walls of the pit in which the Sphinx was carved. While the hydrological and geological findings are relevant, the proposed conclusion can in no way be based on these findings alone, as two fundamental parameters are missing from this study: the topography of the Giza Plateau and the upheavals that affected it during the construction of the Khufu and Khaphren pyramids. The introduction of these two parameters leads to a completely opposite conclusion, confirming the fact that the Sphinx was indeed sculpted during the construction of the Great Pyramids, more specifically under the reign of King Khufu, as demonstrated in the main document.

**Erosion of the Sphinx enclosure**

As we saw earlier, the Sphinx is a one-piece sculpture carved directly into the bedrock, the head from a rocky outcrop and the body by excavation, in effect creating a pit several metres deep around it, lined with vertical walls; in short, it literally emerges from its own quarry.

Wind and sand erosion have left more or less deep horizontal marks on the walls, depending on the quality of the limestone strata, while rain erosion, due to water run-off, has cut vertically into the same walls.

As can be seen in the photo above, the most significant rain erosion is on the vertical west (bottom) and south (left) walls of the enclosure, while the lower north wall (right) is less marked.

In the two photos below of the west wall, the runoff appears to be relatively evenly distributed along the entire length of the wall, indicating a steady flow of water from the overhanging quarries between the monumental causeway of Khephren and the pyramid of Kheops.

To the north of the pit (elevation 20), the pyramid of Khufu stands at a higher level (elevation 60), creating a barrier with the pyramids of the Queens and the Royal mastabas in this part of the Plateau. Between the two, the land slopes southwards, as shown by the direction of the strata on the western wall of the pit.

The two photos below show the south-western corner of the pit and the monumental causeway that runs a few metres alongside it. On the south wall, the marks of water run-off have carved deep vertical furrows.

The pit between the back of the Sphinx and the west wall has also been partially filled in.

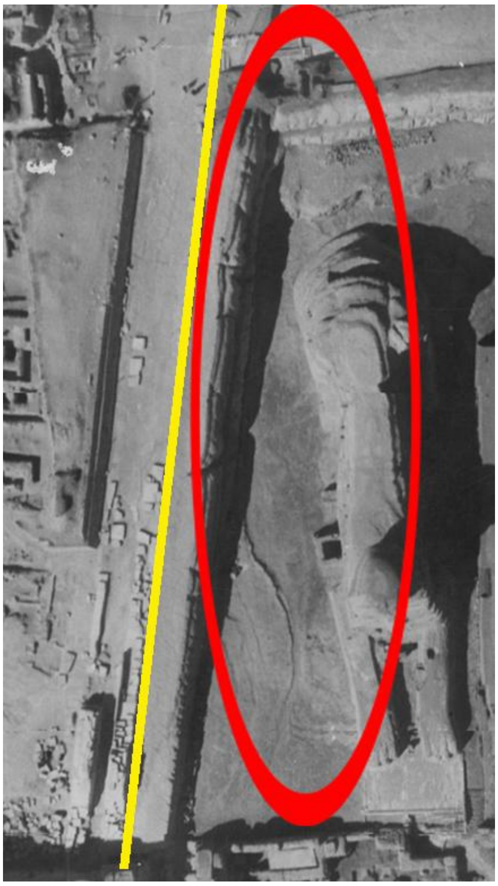
Details of the pit walls in the southwest corner


The photo below shows the southern wall as seen from the south-western corner of the pit and the nearby presence of the (reconstructed) masonry of the northern wall of Khephren's monumental causeway. It can be seen that in the first section, near the south-west corner, the erosion marks caused by water run-off are very pronounced, and the wall approaches the monumental causeway in "steps" (the shadows confirm this phenomenon); in contrast, in the second section, closer to the Lower Temple, the wall is much less eroded and no longer has any steps. Run-off water has therefore not eroded the southern wall in the same way along its entire length, and the "free passage" between the wall and the monumental causeway is narrower in the first section.

The space between the pit and the masonry of the monumental roadway is heavily eroded at the top; there is also a marked sense of run-off erosion at the bottom of the pit.

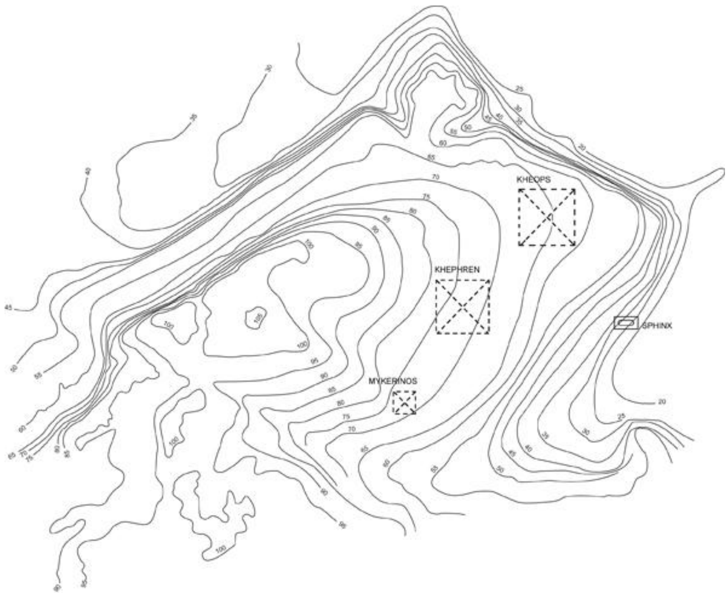
Close-up of erosion at the bottom of the pit

In this aerial photo, we can see all the details mentioned above, particularly the path of the water run-off at the bottom of the pit, which originated at the top of the most eroded part of the southern wall (red ellipse). An element visible in this photo is now of particular importance: the base of the masonry of the north wall of Khephren's monumental causeway (yellow line). This covered masonry causeway ran from the north/west corner of the Lower Temple to the Upper Temple to the east of Khephren's pyramid, the distance between the two being around 500m.

Finally, in the photo below, we can see that there is no trace of marked erosion due to runoff in the bottom of the northern part of the pit, to the right of the Sphinx, confirming a cause-and-effect relationship in the southern part (left).

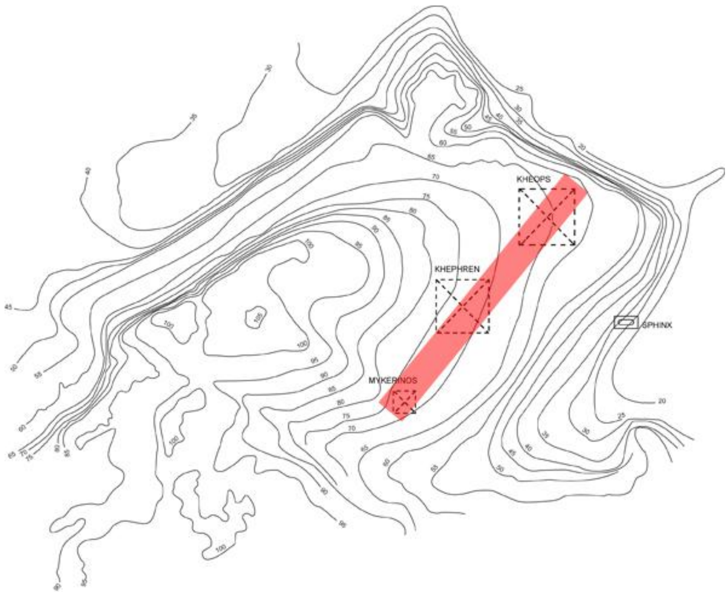
**The topography of the Giza Plateau before the pyramids were built**



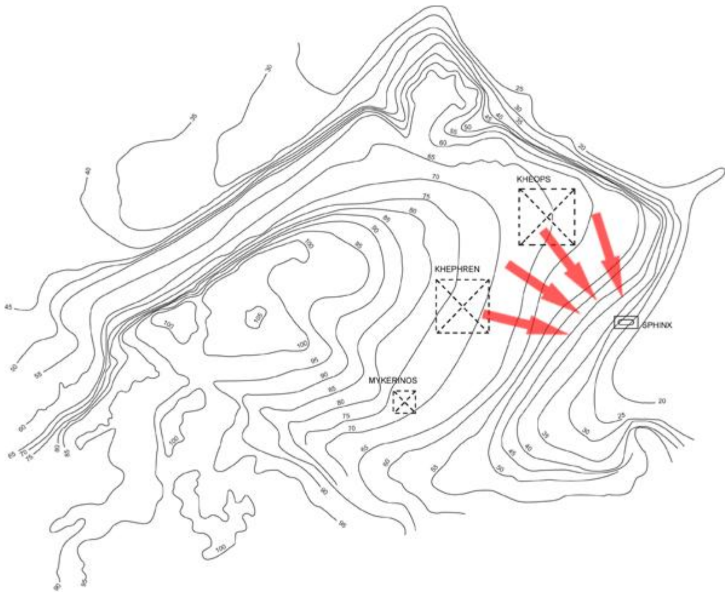

(North is at the top of the image)

As can be seen from this topographical survey, the contours of the Giza Plateau form an inverted "oyster shell" seen from above and oriented east-west, with the lowest point to the east at elevation 20 and the highest point to the west at elevation 105. This "shell" is bordered to the east, north and west by cliffs, and to the south by the course of an ancient, dried-up waddi, which has carved out its bed from west to east, as shown by the bowl-shaped contour lines.

On a central oblique line running northeast-southwest, the Egyptians successively built the three great pyramids, adapting them perfectly to the terrain: the first to the north, the Pyramid of Khufu, straddling hill 65; the second in the center, the Pyramid of Khufren, straddling hills 70 and 75; and the last to the south, the Pyramid of Mykerinos, between these same hills. As for the Sphinx, it was sculpted to the east, between dimension lines 25 and 30, with its head carved out of a rocky outcrop at this point.



Originally, rainwater runoff followed the natural slopes of the topography. Thus, all rainwater reaching the ground in the area of the "shell" between the future pyramids of Khufu and Khaphren and the future Sphinx, flowed towards the south-east of the waddi, increasing in speed as the slope increased, to end up in the bed of the Nile.

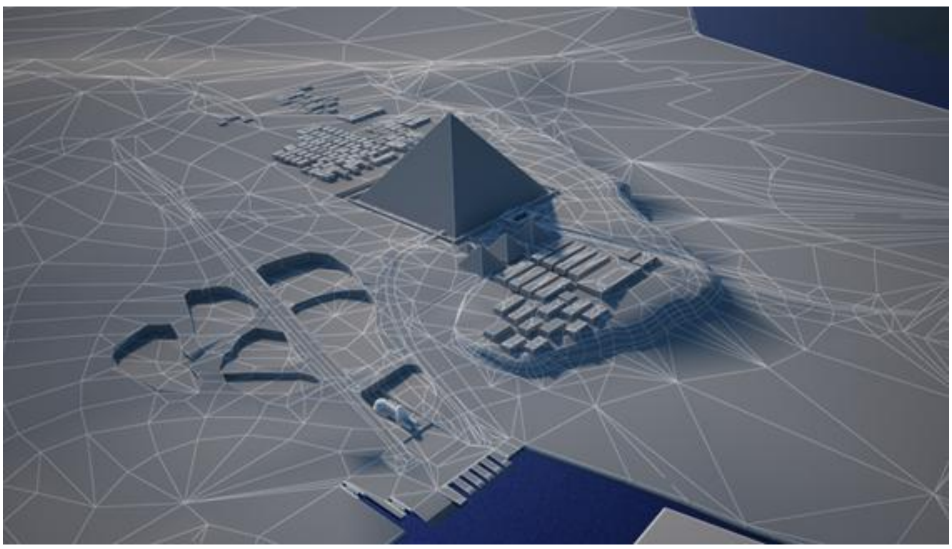



**The topography reworked for the first time during construction of the Khufu pyramid**

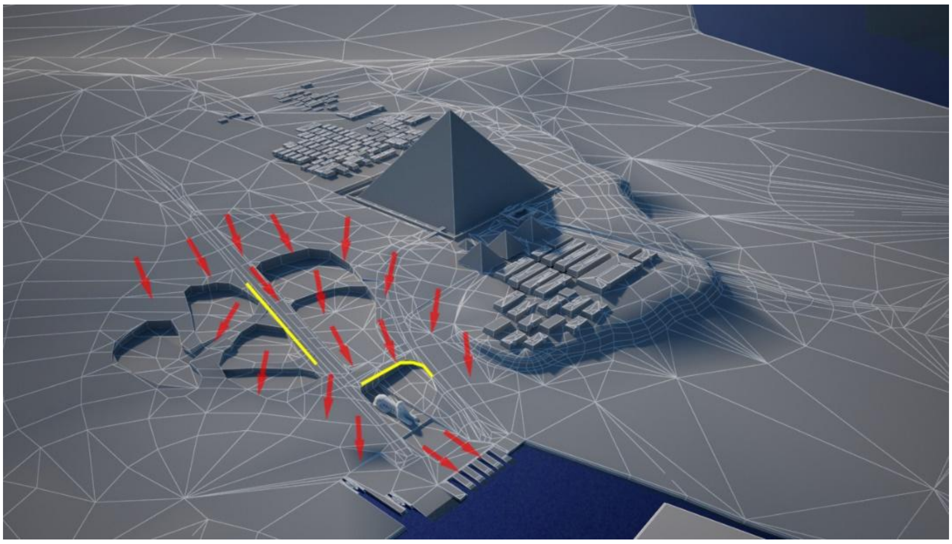
During the construction of the Khufu pyramid, two major developments changed the topography of the Plateau:

- Construction of a ramp linking the site's port to the base of the outer ramp built temporarily to supply the site with materials.
- The opening of the main quarries on either side of the harbour ramp, which supplied virtually all the limestone blocks used to build the pyramid, behind the Tourah limestone facade blocks.

At the end of construction, the Plateau had the appearance shown in the 3D study image below



The quarry to the north of the harbour ramp collected much of this water and diverted it towards the pit in which the Sphinx had been sculpted, before it flowed into the harbour and the Nile. The western wall of this pit then began to erode evenly along its length, while the rest of the runoff spread over the harbour ramp and the quarries to the south of it, before joining the waddi and the Nile.



The red arrows indicate the new course of run-off water following the construction of the Khufu pyramid. The yellow lines show the first rain erosion on the quarry walls (erosion that can be seen today in the Sphinx pit and in the quarry south of the port ramp).

Erosion, represented by the yellow line on the 3D image, on the western wall of the Sphinx pit

Erosion, represented by the yellow line on the 3D image, on the north wall of the low quarry along the south side of the monumental causeway.

After the construction of the Khufu pyramid, rainwater runoff on the Plateau had changed, but the erosion caused by it was still widely distributed across the land.

**The construction of Khephren's pyramid disrupted the flow of rainwater, creating a gutter effect.**

The location of Khufu's pyramid is the result of a choice motivated by economic considerations. Indeed, the architects took full advantage of the topography and facilities already built during the reign of Khufu to offer King Khufu a pyramid to rival that of his father, at a much lower cost. The project can be summed up as follows:

- The pyramid is fifteen metres higher than the pyramid of Khufu.
- An area with a steeper gradient, enabling more bedrock to be preserved beneath the pyramid, and thus much greater savings in material requirements than with the Khufu pyramid.
- The pyramid was built in an imposing quarry, which limited the transport of much of the material.
- A smaller square base (215m instead of 230m), a steeper slope (53.1° instead of 51.4°) for a slightly lower height (143.5m instead of 146.7m) and a total volume 372,000m3 lower (2,211,000m3 instead of 2,583,000m3).
- A much more basic interior layout, with the funerary apartments "dug" into the bedrock parallel to the construction of the pyramid, without the need to install any constructive devices like the Grand Gallery in the Khufu pyramid.
- The reuse of the port ramp at the Khufu construction site to create the Monumental Causeway linking the Valley Temple to the Upper Temple.
- The "clever" visual integration of the Sphinx and its Temple into the new funerary complex without detracting from their original function.

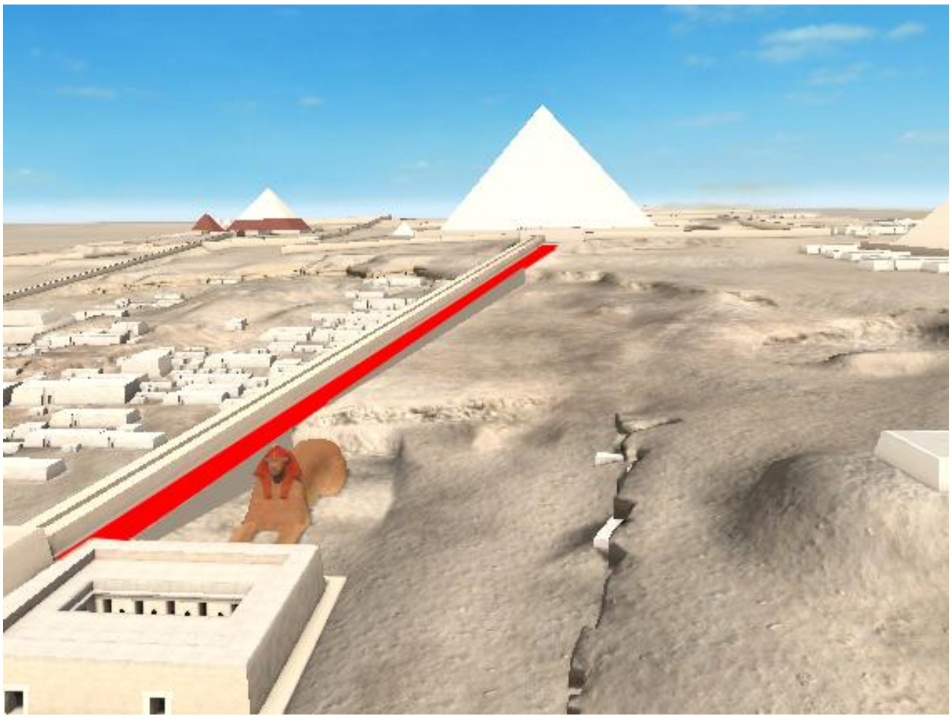
It's clear that the architects have succeeded, for the Pyramid of Khephren sits majestically on the Giza Plateau, often stealing the show from the Pyramid of Khufu in photos taken by the millions of tourists who pass through every year, or illustrating magazine covers with the caption: The Great Pyramid.

However, one parameter had apparently not been taken into account by these same architects: rainwater runoff, which would become a difficult problem to manage once the work was completed.

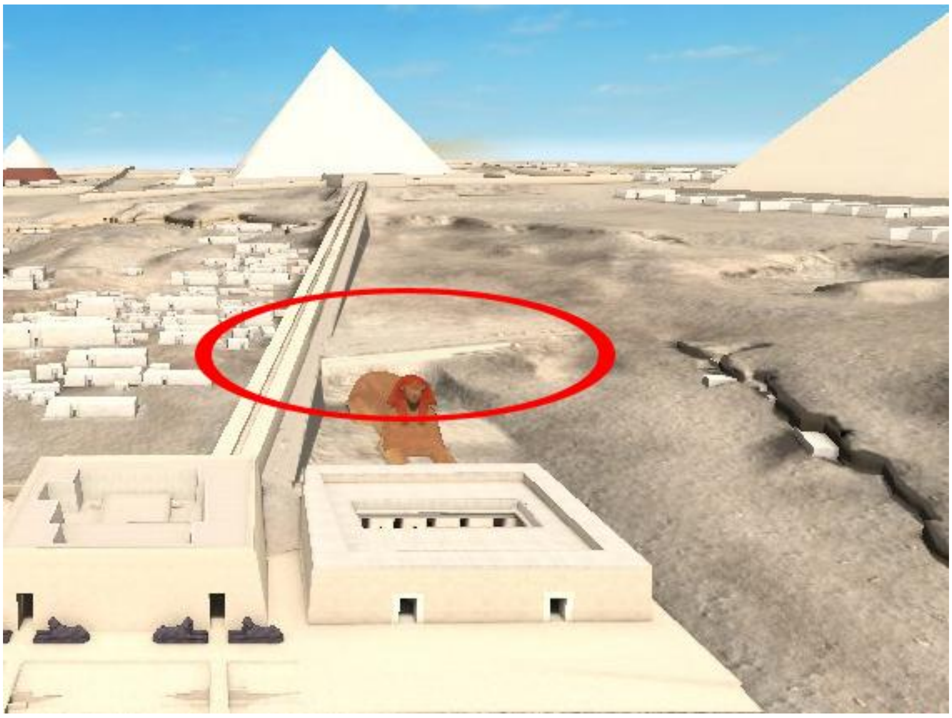
This 3D reconstruction of the Giza Plateau shows the three completed pyramids and the quarries that were used to build them, as well as an imposing masonry barrier in the middle of the quarries that completely divides the topography of the site into two parts: the Monumental Causeway of Khephren.

As we saw in the previous study, this Monumental Causeway was built on the former port ramp of the Khufu construction site, with this all-important detail: the masonry causeway itself was only around ten metres wide, while the underpinning ramp was around 24 metres wide, leaving a paved "sidewalk" on either side of the causeway of around 6 metres in width. The sidewalk to the north of the roadway began at the eastern exit of the Upper Temple and ran alongside the roadway as far as the Temple de la Vallée, flush with the natural topography in two precise places: the first tens of metres from the Upper Temple to the vertical wall at the western limit of the northern quarry, and the area between the eastern limit of this quarry, above the Sphinx pit, and the Temple de la Vallée.

All along the northern quarry, a vertical wall, decreasing in height from west to east, bordered the northern sidewalk. Without realizing it, the architects created a veritable "gutter" consisting of the northern masonry wall of the roadway and the sidewalk, some 6 meters wide at its base.



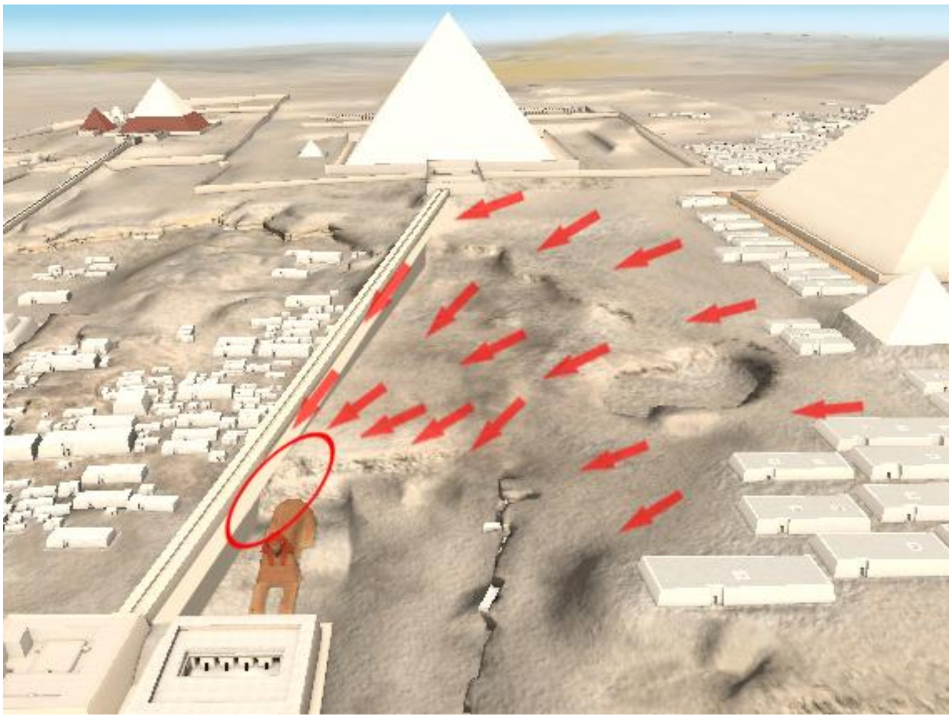
The red-highlighted "gutter" running alongside the Chaussée Monumentale.



At the end of the construction of Khephren's pyramid, the eastern part of the northern quarry, overhanging the Sphinx pit (inside the red ellipse), was flush with the northern sidewalk in its south-western corner.

A further change in the course of rainwater runoff from this area of the Plateau ensued, materialized by the red arrows on the 3D image below, with a bottleneck forming in the south-west corner above the Sphinx pit (highlighted by the red ellipse), with water flowing down the gutter telescoping with that flowing down from the entire area north of the Chaussée Monumentale. The flow became literally tumultuous at the junction point, with the pit becoming an outlet, the water gullying the vertical walls in the area as well as the bottom of the pit as it continued its way towards the port and the Nile.

This greater erosion was therefore not due to more frequent and heavier rainfall, but rather to a sudden increase in the quantity of water running off a specific point during a rainy period. As proof of this, anyone who has witnessed a thunderstorm in Cairo will have noticed how violent it can be, as the amount of water received on the ground in a very short space of time can be very significant.



Despite the fact that the quarries to the north of Khephren's Monumental Causeway have filled in over time, it's easy to see from this panoramic photo that all run-off water converged on the area circled in the 3D image above and on this one.

Let's return to the theory that the Sphinx was carved at a time long before the pyramids were built, during a period of very heavy rainfall. The main question that immediately springs to mind after analyzing the terrain's topography is this: why, when the natural flow of rainwater, as we've seen, follows a north/north-west to south/south-east direction, is the vertical wall most eroded by runoff the one to the south of the Sphinx's pit, and the slope continues south/south-east after this southern wall? In a general topography not altered by the construction of the pyramids, the west and north walls would logically have been the most affected, and the south wall would have been preserved, as water never rises up a slope...

For erosion to look like this, a disruptive element had to be added to the topography: this element is Khephren's Monumental Causeway, which "redirected" run-off water towards the Sphinx's pit. There is therefore no valid climatic argument for asserting that the Sphinx was carved 10,000 years ago.

Khephren's Monumental Causeway channeled runoff into the Sphinx pit.

**Did the Egyptians take any measures at the time to deal with the run-off problem?**

The question is raised when we take a closer look at some of the details on the site, along the Chaussée Monumentale and in the Sphinx pit.

Halfway along the Chaussée Monumentale (red circle on the aerial photo below), on the north and south sides of the road, are the outlets of a tunnel dug beneath the carriageway. This may originally have been dug to evacuate run-off water from the sloping quarry floor to the north of the Chaussée Monumentale.

The type of piercing is rather curious, reminiscent of a concrete nozzle found under roads to let rainwater through.

View of the tunnel entrance on the south side of the Chaussée Monumentale.

Analysis of the interior of the tunnel itself seems to confirm this function as a rainwater outlet to the south. A vertical shaft was dug in the roadway itself, in the southern sidewalk, but this appears to have been dug at a later date.

The tunnel crosses the Chaussée Monumentale a few meters below it. Traces of stagnant water are clearly visible on the side walls and at the bottom.

View of the tunnel entrance on the north side of the Chaussée Monumentale. The Chaussée Monumentale has been partly filled with sand, as has the quarry that runs alongside it. The bottom of the quarry and that of the tunnel must both have been at the same level.

This detail is also to be found under the Monumental Causeway of Khufu, in the part near the Upper Temple (below).

It seems clear that this relatively shallow tunnel was not intended as a passageway for humans, but more likely to evacuate run-off water.

Moreover, the Sphinx has long been the subject of alternative theories as to its function; the best-known of these is that an entire network of tunnels and secret chambers was dug into the bedrock beneath the Sphinx, and that the archives of a lost civilization are locked away there. However, this theory is not based on any tangible evidence, but on highly unrealistic speculation. What we do know is that there are three vertical shafts dug into the pit in contact with Sphinx (one to the rear, one to the north and one to the south), and that penetrating ground radar (GPR) surveys confirm the presence of underground voids.

A controversy arose a few years ago when the Egyptian authorities acknowledged the existence of these shafts and tunnels, one of which would stretch, at the very least and from west to east, from the back of the statue to the legs, where a masonry wall would block the passage, but without giving any further explanation; this silence naturally led to renewed speculation on the subject.

The explanation for the presence of these shafts and tunnels could be far more rational than anything that has been put forward: the Egyptians would in fact have created a drainage network to combat the flooding of the Sphinx's pit by run-off water. The position of the shafts flush with the body of the Sphinx, to the north, west and south, make them veritable avaloirs that would be connected to the tunnel that runs from west to east, the latter continuing well beyond what was visited, to flow into the site's harbour a few dozen metres away. The authorities' silence could be explained by the lack of purely archaeological interest in such a device.

But even more interestingly, we have irrefutable proof that the builders of the Mykerinos pyramid (or their successors) also had to contend with the problem of rainwater run-off. In fact, following up on the excavations undertaken by Georges Reisner between the wars, Dr Mark Lehner and his team have uncovered drainage and rainwater diversion works, dating back to the time, in the area of the Mykerinos Valley Temple, which had also undergone several reconstructions following major damage. A masonry weir was discovered slightly south of the north side of the Monumental Causeway, very close to the Valley Temple (see the red ellipse on the 3D infographic below).

As you can see, the Mykerinos Monumental Causeway once again cuts the Giza Plateau in two. It would seem, then, that the problem of rainwater run-off was a recurring one, due to the impassable barriers created by the Monumental Causeways. You can't think of everything...

In conclusion, let's not forget that over time, the entire Giza Plateau was buried under sand, and the Sphinx pit was filled in, as were the surrounding quarries. We know from the stele of Thutmosis IV that the Sphinx was already completely silted up by 1400 BC; the silting-up of the Plateau can be traced back to the First Intermediate Period, around 2100 BC, when the necropolis was invaded by dwellings and finally abandoned at the beginning of the Middle Kingdom. The main erosion of the Sphinx pit by air, sand and water was in fact only possible over a relatively short period, less than 4 centuries, compared to the age of the Sphinx, which has been enigmatically looking east for 45 centuries.