XXIII
Transportation of the Blocks

It is known that the most of the Great Pyramid was built using limestone blocks from local quarries just a few hundred meters to the south. However, limestone of superior quality, almost white and very fine-grained, has been used for the internal parts of the corridors, all the Great Gallery and the outer casing of the pyramid (alas looted). Finally, do not forget the granite.

These two different kinds of stone come from sites far to the south, so it requires a transport by barge via the Nile.

Nothing new, but since the same problem must have surfaced for other pyramids too, I checked and discovered that all these great construction were carried out in the vicinity of the Nile and all are equipped with a "Priestly Path" connecting it to the river.

A good, sturdy, sufficiently polished base of limestone would have been necessary that the large blocks coming from the port could be towed.

Later on this path may be embellished with temples and statues, but its initial purpose was certainly different.

Of course the width of the "Priestly Path" must be connected to the size of the larger blocks to be taken along it.

I have come to this conclusion by working backwards, starting from the large blocks inside the pyramid of Cheops.

The largest are the monoliths of the Zed, which have astounding measurements and weight: perhaps even more than 50tons (or even 70tons!) with lengths of nearly 8m.

There is something in our way of thinking, though, that we need to correct; something coming from our familiarity in modern techniques and materials, but leading us astray when we try to understand the methods of the Ancient Egypt.

The first big mistake is to imagine long rows of men to tow using ropes, similar to steel cables.

This requires a large space available upstream; indeed often the space is not enough but, above all, that is an impossible task for the ropes of the era.

This to tell you that the great blocks (including obelisks) were not moved as per their longest side, as we would be led to believe, but perpendicular to it, using very many ropes and shortening the worker rows.

Of course, this requires a suitable area, appropriately prepared and leveled by clay first... (we shall see later the problem of the pressure exerted onto the ground).
I then questioned myself: is the Priestly Path of the Cheops's Pyramid wide enough to allow the Zed blocks to climb while in this position?
The plans show a width of about 9m; so here we go.
But not so fast: the measures comply, but to succeed in the enterprise...(?...!). And more, having the towing problem solved, could the blocks be lifted up to the Zed height?
Last, the problem of over 2,300,000 blocks of local limestone, coming from the quarry and climbing up along the slope of the pyramid, on a dirt ramp...
Thinking rationally, we understand that we are not dealing with a single problem, so maybe different techniques, having little in common between, might have been adopted. First let me explain the raising of the large Zed monoliths, giants placed at mid-height of the pyramid and apparently prevented to rise, given the lack of any clay ramp.
The solution, in my opinion, is not complicated at all; wanting to be too smart, one often ends up missing the obvious.
In this case, however, the error was committed from the outset: by denying the evidence of a global project, lengthily pondered, where everything has been meticulously planned, inevitably nothing much can be grasped.
Actually, there is another problem that must be solved: in spite of their hardness, three out of four of the long sides of these giants were machined and polished to perfection.
For us, polishing limestone or granite is almost the same, but to work upon granite at the time, without even iron tools, had to be a terribly long-winded job. During the journey from the quarry, the blocks were still raw on at least three sides (the fourth, facing upward, had been already polished and worked upon). That means the process had been carried out on site, over several years.
I remind you that, unlike marble, even special steel chisels cannot work upon granite: it is too hard, and every hammer blow tends to splinter it along unpredictable crystalline veins. To achieve a smooth surface, excess material would have to be removed patiently by strokes vibrated with care, using a bat or a ball of hard stone, as it was done at the time.
In this way, as the smoothing is going on, the work will become longer and more complicated, since the small projections which must be stricken multiply while it becomes more difficult to adjust the intensity of the blow.

This process had to be extremely time-consuming, even if the employees worked alternately from dawn to sunset. Furthermore a man at work needs a space that cannot be shared with neighbors...
I know that in some cases a copper "saw" maneuvered with leaking water and sand has been used to cut granite stones. But that seems to be more a "specialized workshop" method, to be used by very few experts and not suitable to such big work...
At the entrance of the pyramid of Menkaure, we can observe how the granite smoothing was done in situ after the block installation (photo **N01**).
Even in pre-Inca archaeological sites of South America finely crafted granite blocks have been found with smooth surfaces and squared as those of the King's Chamber. I presume that, in both cases, the technique used was the same: a first processing by means of percussion with hard stones, followed by a long wet sanding with abrasive powders.
I would have to propose an interesting method to couple granite stones perfectly, even with complex profiles, such as those that can be observed in Machu Picchu, but at the moment I have something else to do. Maybe elsewhere and at another time, who knows...
Ultimately, each Zed block required, in my opinion, years and years of patient work. For this reason, I figure that once Hemiunu obtained approval for his project, he immediately began to extract the large monoliths in the distant quarries, even before starting any work at Giza.
No ramp, however, could ensure the integrity of the so-perfectly smoothed surfaces (not to mention the problem of the slope).
No ramp then, at least not for these monoliths.
It is evident there are two problems to be solved: first the big blocks to lift up to the Zed, and second the need to have a safe place where to work on, without haste, over several years.
Well, there is only one place where both, the long time and the lifting, can be solved. It is the most obvious: the pyramid itself. When the first layer of the pyramid base will have been completed, all the monoliths will be taken up, gathering them in one place, where the finishing operations will also begin.
In the meantime, more limestone blocks, to build the second layer of the pyramid, will arrive.

In due course, all the big blocks will be moved onto the next layer by using a modest slide in clay; the empty place in the previous level filled by limestone blocks and the process will continue.
One could speculate that climbing in this way, the blocks would move along a spiral path, tracing the pattern of the impossible ramp. But I believe that the great monoliths were simply moved along the north-south route, remaining constantly close to the eastern edge.
I am convinced that, at the other three sides of the pyramid, were operating a large number of small ramps (which I will describe shortly): useless to slow down the work by closing the access of some ramps...
In conclusion: it isn't necessary to build a suitable ramp for the monoliths.
At the same time the finishing work will continue calmly, since it will take many years before the Zed level has been reached.
Certainly, everything has to be carefully planned; providing perhaps a few more monoliths, just in case. Also the granite blocks of the King's Chamber, the large blocks of the truss and the longitudinal projecting beams of the Grand Gallery could have been raised that way.
Working in this way, a free area would certainly be necessary to store the blocks and start the processing, waiting for the base of the monument was built. What better place than the area on which the temple will be later built, next to the pyramid?
Also the site of the temple downhill was previously used to store the large blocks from the barges.
Returning to the ascent of the monoliths: I am really surprised that a solution so obvious it was never advanced by any of the experts. Of course this is the consequence of the idea of the overall project.
Frankly I do not understand why this fact should be so opposed by the professionals; of course, this awareness would place them in front of an absolutely extraordinary mind and perhaps the comparison may be merciless...
Agnese gave me some photos taken in the vicinity of the north side of the pyramid, where there are, dug in the rocky ground, a series of semi-spherical little holes, spaced well apart and making a repetitive, well-designed pattern (photo **N02**).
He claims that vertical poles were stuck into the cavities allowing the existence of sort of shantytowns for workers and materials. I don't agree: all the blocks would have to converge to this spot, and the traffic had to be nothing short of chaotic. I find a fixed settlement here unlikely.

Needless to say that these cavities bring to my mind another very special one inside the pyramid, exactly in the middle of the Horizontal Corridor leading to the Queen's Chamber (photo **G14**).
Impossible that there is no connection, I told myself.
Let’s imagine going back to the Horizontal corridor when the statue was advancing inside.
I have already said that there have been problems, such as the base of the statue being stuck inside the corridor several times, forcing the stonecutters in a frantic work of chiseling the surface of the walls to allow its passage. I've also said that pushing from behind was not very useful as the small space available, at best, a battering wooden ram could be used with great caution.
But the statue had to be towed inside the corridor with the looming problem of insufficient air.
I estimated at least 40 men engaged in towing, but the little hole in the middle of the corridor could mean that the number was actually much lower, probably not more than a dozen.
This might be more likely although, in this way, the working time would be more and the air requirement does not change.
Cause the ventilation ducts have been found closed, the airflow between the walls and the statue, albeit modest, was enough for the men involved in the task.
By the way: from the measurements of Gilles Dormion the second half of the corridor ceiling is 118cm tall, while at the Quadrivium it is 117cm; perhaps this change was planned....
As an old physics teacher, I would like to know the kind of lever that was used.
If there were a series of equally spaced little holes, the explanation would be obvious: maneuver the lever as possible, move to the next notch, and tow again... so we would do now, but in those days?
The knot could also be untied to reduce the rope-towing gap, but this is an impractical solution... too long and the knot would reduce the useful distance.
May we have lost the memory of a towing method— both beneficial and more versatile—than those known nowadays?
Pondering over the little hole, I have invented a particular lever, already tested in a model and, in my opinion, it was widespread in the Ancient Egypt.
Even if you do not agree, please grant me the merit of inventing something simple and effective (I will explain it to my students in the classroom, along with the other levers).

This is a lever of the second type, used by pivoting it into a soil cavity, with the rope from the statue located very close to the ground and the other, to the pulling crew, positioned at the top. It is evident that the advantage depends on the ratio between the two lever booms.
According to the corridor height, there may be a lead of between three and four. Such a lever, however, after having exploited its gap, would require, as I said, the rope knot to be untied or a new rearward hole to recover the rope gap for the next pull and so on. It is not likely (the time is pressing); even the smaller additional holes (suitable for small adjustments by a crowbar), random positioned, are not useful...
Hence the idea.
Instead of using two ropes for leverage, one from the statue and one toward the men, just a rope will be used, coming from the statue and twisting around the pole, starting from the bottom. After few turns on the pole, having increased the lever boom to get a better effort, the rope will go to the pulling crew. The effort completed, an attendant shall provide the new rope positioning around the wooden pole, keeping it taut for the next effort.
I made the first model, but it did not work because during the pulling, the pole was induced to rotate due to the acting forces, rendering the device ineffectual.
I am somewhat abashed, given my profession, for failing to foresee the problem; however, while working, there are four twisting moments. Two of these, having as the fulcrum the hole dug in the floor, do not cause any problem, acting as a second-class lever.
Even the other two are mutually opposing, but the force directed towards the statue will generate a torque greater than the force directed towards the men, so the pole will rotate within the hole nullifying the process.
I was sadly noting this effect; regretful that a solution I had right at my fingertips was still escaping me, when suddenly everything fell into place in the simplest way possible.
Imagine then a pole, with a rounded end to be placed inside the floor hole (cylindrical or hemispherical), long as the height of the corridor, having at the top a hole to insert a transversal pole long enough not to touch the corridor walls (imagine a tree with a branch).
The rope comes out from under the statue, twisted for a few turns in the right direction around the main pole (the attendant will take care of the correct height from the ground) then, instead of heading straight to the men, it takes three or four

additional turns around the "branch" from the inside to the wall, allowing the men to generate considerable torque capable of exploiting the new side boom (photo **N03**). By acting on the rope turns we will get the lever (not complicated at all, just try it): the wooden pole will stay in position, well compressed in the hole by the effort of the men who pulling the rope at an angle from top to bottom and having the twisting moments in equilibrium. The lever can be kept for a long time in the same hole if entrusted to the expert hands of a "lever attendant", able to regain the rope slack after every pull, fixing the rope and coordinating any additional activity between a pull and the next (photo sequence: **N04**...**N11**).

A kind of lever like this, placed in a hole exactly halfway down the corridor, is enough to drag the statue from the Quadrivium up to there. For the second half of the path the lever pole will be fixed to the step at the end of the corridor.

I'm sorry the demonstration is so complicated, but I assure you to see the device working is a real pleasure; understand how a skilled worker can vary the ratio between efforts and so the forward speed, just changing the attachment point of the rope on the main pole, but also on the side branch.

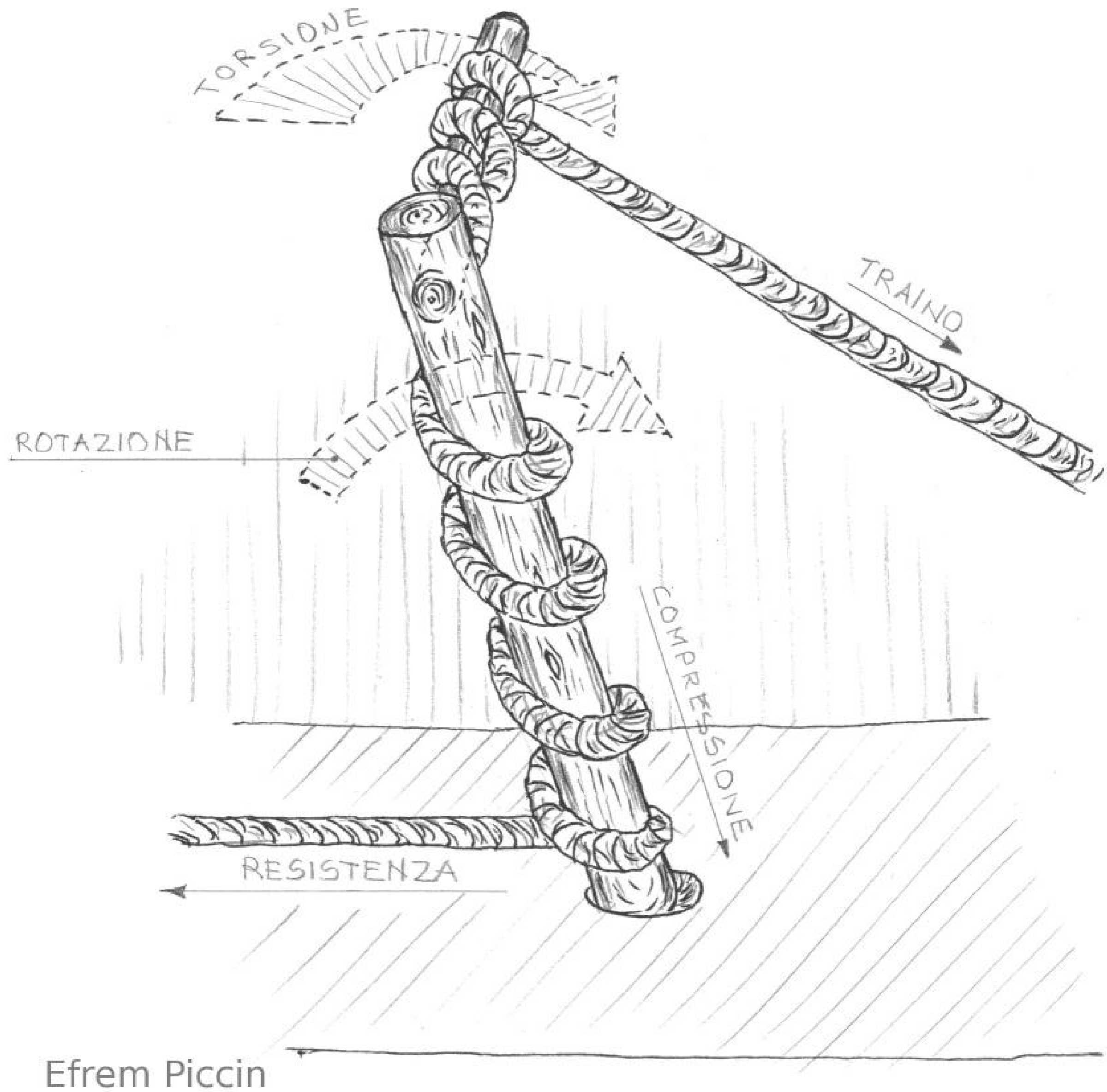

Figure 19: The double lever

Knowing how to make good use of this double lever, if it really existed, had to be almost an art, an art that we have lost.
However I do wonder if, among the many representations of men working in the Ancient Egypt, it is possible to recognize this tool somewhere. I shall address this question to the experts.
Very well then, the method works and can easily be doubled, synchronizing the work of two levers simply by a time "beater", as in the days of the galleys).

The double lever, used to move the blocks, explains the large number of pairs of symmetrical pits dug in the limestone ground from the quarry to the pyramid. Each block was advancing hugged from behind with a double rope supported on suitable wooden corner guards (front and rear). The ropes went to the two levers, housed in the nearest pair of pits available.
We can even venture a calculation: a $1m^3$ block weighs at least 2700kg. Being rough, a friction coefficient of 0.6 can be assigned to it: this means we have to tow with an effort of at least 1620kg.
The route is along a few hundred meters and, since the workers were not particularly motivated, I guess every man produced an effort of not more than 20kg, 80 men were necessary for each block. If a double lever, like the one I have described, had been used, with a reasonable 4:1 advantage, just 20 men, plus the lever attendants, would have been enough.
At the south side of the pyramid are gathered, placed on their narrow side, a number of fine, well-worked, large limestone blocks recovered from the roof of the large pit containing the sacred boat, now kept in the horrible building defacing this side of the pyramid (photo **N12**).
By a thorough examination, it jumps to the eye that they were not being transported in the current upright position, but by being slipped over one of the large faces, before the last finishing, dragged by ropes housed in round grooves made in the rear corners of the blocks themselves.
There's more: at the towing side coarse, semi-spherical recesses have been carved on both sides of the blocks. I suppose short wooden beams were stuck within, held in position by the side compression of the ropes, to create a front protection. We have to keep in mind that any course corrections when towing, would bring the strings to rub against the front edges of the monolith.
More about these blocks: their fine-grained limestone means they came from Tura, traveling in barges and then going up along the Priest's Path where any lever pits were absent.
This suggests they were taken up on their coarse side by two groups of workers (these blocks having a modest size).
The next question is: on what were the blocks from local quarries put on, during their journey?
There are two theories: the first by using slides and the other by round wooden logs placed under the stones, rotating during the progress.

Oh, I almost forgot, a third one speaks about logs under the slides. Needless to say, none of these convinces me.
The wood was rare and imported for a high price. No slides then, at least not for routine work. Of course, an exception can be made, for a statue for example, but not always. No slides for the pyramid!
What remain are the palm trunks, quite good for the task, but we have to face it with a different point of view.
I've seen movies where logs of the same size (and this is a problem!) were placed transversally under a block.
When pushing or pulling blocks everything seems to work at the beginning: but the small differences in the log diameters will produce a zigzag rolling, tangling them with each other, making the device useless.
In 2004 I solved this problem by means the " short logs technique " mentioned by Herodotus about his visit to the Great Pyramid.
I told myself a so obvious and well-known solution did not deserve even the trouble of an explanation.
Incidentally, I happened to read some translations of what he wrote about the chamber in which laid the Pharaoh, always mentioning an underground room where the Nile water flows...
I find this description disquieting since that room actually exists, not underground but "internal" and was flooded by water poured from the top (according to my theory).
It may be that the misunderstanding is due to the translator or, perhaps, Herodotus has misrepresented what has been reported: if the water of a river floods a room, it is logical that it should be under the ground...
Back to the block transportation: if the block were placed at its sides over a double string of short palm logs, we would have a free central channel under it. The idea is to use this gap to insert the pulling stone I have already described elsewhere, although its bottom side would be shaped a bit differently than that used within the Ascending Corridor.
Keep in mind that these towing stones never have to support any block because the lower thickness than the trunk.
These trunks have to be continuously inserted from the front side as the block advances (the "short logs" precisely). Working in this way, the logs can also be induced to get across, but being short will quickly be taken out, especially if placed

slightly like a fish bone. New logs in front and a diligent lateral work with small clubs, will allow the towing to proceed.
The softness of the palm-wood does not makes it unfit for work, on the contrary, this elasticity makes up for the small differences of their diameters.
At the time, Saraò made a good model of this device and it worked pretty well.
Instead of palm-logs, we used short pieces of mountaineering rope, and the ground floor was simulated using a double layer of soft fabric. The block was advancing very well even for long stretches; at the time I wrongly insisted on using a system, which consisted of a ladder as an effort multiplier, using the workers weight as a towing force.
It seemed to me almost revolutionary but to build a ladder like that, it is necessary as much wood as for a sleigh...
No ladder then. The use of palm logs, at least to move the blocks horizontally on a soft ground, is a good idea, but on a limestone ground, not very coarse, the mere sliding is the best solution.
The friction coefficient between two stone surfaces, fairly smooth, has a value of about 0.5.
I have tried it out several times in the school laboratory and the results were encouraging; often the result was even better (perhaps sometimes the friction coefficient is lower).
Inserting a wooden sled, the work would worsen!
We will then have the best possible friction coefficient between stone surfaces, after a coarse smoothing.
Furthermore if, during towing, some water would be poured, the ratio would decrease further.
In this way the construction work of the pyramid was simplified. The limestone blocks, roughly shaped at the quarry, were simply dragged lying on their sides along the well-honed rocky path, from the quarry to the pyramid, using the two-lever system.
The free sliding on a rocky floor, in my opinion, is the best technique, at least up to the base of the pyramid.
Next step is the climbing onto the clay ramps; here things get more complicated.
Some photos, taken in the vicinity of the northwest side of the pyramid (i.e. the flat area with the little holes) show a step about 10-15cm high near the pyramid base.
The edge of this frame does not have a regular pattern, but follows a kind of whole polygonal with sides running perpendicular to each other (photo **N02** and **N13**).

Maybe I have found a solution. You may say that it is a bit fanciful, but because it makes sense, I offer it.
In my opinion the faces of the blocks coming from the quarry were differently finished: the topside well finished in the quarry, cause the long time available. About the four lateral faces: the two facing inside the trench pretty well finished; the internal two just like the fracture surface. This means contiguous blocks would have to travel together in order to arrange them side by side (see photo **N14**).
Last the bottom side, for sure in poor condition, because just removed.
In my opinion, these blocks were tipped over on one of the two fairly finished sides immediately after extraction, and moved to the pyramid as described above.
At the immediate vicinity of the pyramid, the blocks were again turned over, on the smooth side, ready to be towed by a new device up to the clay ramps (?...!).
The polygonal frame edges, offset from each other, were used to turn over the blocks without interfering with the next team. The small step was the edge used to turn the block upside down.
Lest I forget, I describe now what I think was the procedure of block installation after climbing the ramps. Blocks (turned over from their current position) were dragged on the working floor to their place. Then the masons could finish the last side, still rough, and now facing upwards allowing any height adjusting of the blocks.
It might seem that the many block overturns is only the work of a twisted mind, but perhaps there is a shred of evidence: if I am right, all the blocks would be placed upside down with respect to their original position in the quarry.
Agnese told me the local limestone has incorporated some fossilized organisms, clearly visible (it seems to me that he called them nummulites). I know nothing of these little beings, but being provided with a shell, it is belive that we can recognize in them some asymmetry between the top and bottom, and this should be able to help you figure out if the blocks for statistical they have been inverted or not.
Now the towing along the clay ramps.
These ramps cannot have a high slope, to avoid any increase in the effort of the men involved and, furthermore, the risk of blocks sliding back downward. For this reason I think the use of round logs is unlikely even by inserting wedges from behind or any other device.

In my hypothesis the blocks, at the polygonal frame near the pyramid base, have been laterally overturned onto a double string of small limestone blocks, all identical and well squared, placed very close to each other.

These two strings form a stone bed on which the blocks will move, sliding on their smoother faces.

To complete the device, in the bottom groove between the stone strings, the pulling stone with a double rope will be installed.

At the upper end of the block strings, a wooden beam, as wide as the block to be towed, shall be inserted compacting with each other the string blocks during stress.

A thick copper plate, L shaped, will be installed against the beam side, against which the levers have to work.

One of the two sides of the L (at least 15cm wide), being on the ground, prevents the levers entering into the soil and damaging their bottom ends, while the other side, leaning against the beam, protects it from the friction due to the rotation of the levers.

I suppose also the lever bottom ends were protected by copper caps (copper can be replaced and recycled: wood is the most valuable material).

Let's see now the special shape of these levers that, going along with my hypothesis, is of a kind still different from those described so far.

The idea came to me while thoroughly observing some photos taken in the temple near the Sphinx.

In particular, right at the east entrance and close to the granite threshold, are clearly visible two little hemispherical holes dug in the floor (alas now cemented, as there the tourists go out from visiting the sphinx) (photo **N15**).

Carefully studying the plan, it is possible understand how, by inserting levers inside the two hemispherical cavities, it was possible to drag along the external limestone ramp a heavy statue to be housed in the back of the entrance hall.

In this case too we have the two fixed levers and some tens of meters of rope to recover.

Looking back upon the levers previously described for the Horizontal Corridor, I realized I needed to adapt it to the new task while keeping in mind related problems.

The change is quite simple: two identical levers, with two holes each, tightly coupled by two transverse poles into them, and a double rope, will do the towing.

The ropes, coming from the towing block located at the rear of the statue, will be twisted around the levers from the bottom up to and then to the workers.

After the first pull, the two cross poles will be removed; the levers thus will be free to rotate to recover the ropes. Then the two transversal poles will be reinserted and everything will be ready for the next pull...
It is not complicated at all and it works perfectly.
This method could easily be adapted for handling the blocks uphill on the dirt ramps providing the two strings of small limestone blocks.
Thinking about it, though, I've come up with a further simplification: the two levers could be made up like a rigid ladder, without the need to remove the transversal poles.
The two ropes, coming from the bottom of the block, intertwine around the ladder lower legs and tied.
On the other hand, the ropes for the workers are tied at the ladder top.
The weight of a worker, hanging at the top of the ladder, can be useful during the last phase of the pull.
First let us speak a little of the size of the supporting blocks to be installed onto the clay ramps.
I estimated reasonable a length of a cubit and a square section having the two sides equal to half a cubit each; in centimeters, 52.5cm long and the square base sides equal to 26cm approximately.
The measurements are sensible, I do not believe the device can be operated with blocks shorter than that, but a problem arises: such a block would weigh about 90kg and it would be difficult to be handled even by two men. I planned one man assigned to each supporting stone because the team (at least 20 men), once delivered the monolith, has to go quickly back to the bottom of the pyramid, carrying the whole working kit: supporting blocks, ropes and levers ... (presumably in a single trip).
No. This system will not work, at least not with the necessary agility, unless to reduce the weight of each block...
But if every block were made of wood, perhaps of Lebanon cedar, weighing about 28kg, the problem would be over but, as I said, the wood is expensive...
It will be expensive, but it may be worthwhile.
Is this the "short logs" method?
In any case, using the wooden blocks, one more question arises: having a so small bearing surface, the clay ramp can withstand the block compression?
Do the math and imagine pulling a 1 m^3 block.
The two block strings have a support surface equal to half of the block base.

We know that the weight of the block is 2700kg.
The supporting area is equal to 5000cm^2 (half of the block base = 1m^2).
The pressure acting on the clay base will be equal to: 2700/5000 = 0.54 kg/cm^2 (a little more than half an atmosphere).
A man of 70kg walking on the same clay base, weighting on a single foot (about 120cm^2 with the heel raised), will generate a pressure equal to 70/120 kg/cm^2 = 0.58 Kg/cm^2.
It may seem strange, but in spite of the large size of the block, the pressure on the strings and then on the ground is comparable to that of a running man.
So just five or six wooden blocks per side are necessary. There will be, of course, frequent interruptions to move the wooden supports, but this is not a bad thing: men can take a breather.
Additionally, keeping the supports well greased for sliding, we would get a double benefit: to lengthen the wood life and reduce the effort of the men.
Naturally just the smooth face of the block will slide onto the supports.
Lastly a not insignificant advantage, since any support block is rectangular shape with a square base, when worn by the friction, a second side can be used for sliding and, last, it can be used as a suitable mallet for the stonemasons (photo **N16**).
Now how the double rope towing works on the clay ramps. Imagine starting a sequence of pulls: the limestone block is resting on the wooden supports (about three per side, well greased and compacted) having in front two or three free blocks per side.
The large transverse beam will rest in front of them, heightening their compaction. This is a precious beam and must not be damaged for any reason. The L-shaped copper plate, described above, is essential to save the beam during the lever rotation.
The lever bottom ends, with copper caps, rotating onto the metal, avoid them digging into the ground and the other side of the L-plate save the beam.
By the first pull, the block will advance to about 20-25cm, creating a slack in the lower rope. For the next pull, to put the lever in traction without untying the ropes, the 25cm gap between the top beam and the supporting blocks will be filled by other two blocks, freed from behind, transversally placed.
The beam will be reinstalled, then the L-shaped copper plate and another pull can be made. A new gap of 25cm will be created so: uncouple the beam along again, place "lengthwise" the two wooden supports, used before transversally, again install the beam, the L-shaped plate, and so on. It sounds complicated, but I built a

beautiful model and everything works properly. I'll attach photos... (photo sequence **N17**...**N54**).
Now we do the math: on the downward trip, we need to carry, just in one trip, all the working tools, and this must be done by the same pulling crew.
There will be about 10-12 wooden blocks, the transverse beam, weighing like two blocks, but one strong man can carry it down, on his shoulder; two men to carry the ladder and two more for the towing blocks.
Someone has to bring the ropes, grease, and L-shaped copper plate... Say another three men.
This is not a demonstration, but if you remember, I had expected a team of about twenty men, and that is....
February 2011: I'm checking if the references in the text correspond to the right photos and drawings. Any reader of my book will be able to track them down by checking into a photo gallery on my website. Even if...
Meanwhile, I could add a part here, hopefully interesting, still on the block haulage.
Inter alia, because I am curious, while surfing the Internet, I've collected a lot of photos relating to the Andean archaeological sites such as Machu Picchu and Cuzco.
The stone walls have caught my attention: I said that I would have to propose a proper method to perfectly join stones with complex shapes, but this is not the right place to do it.
I came across similarities between these walls and some granite blocks in the Menkaure's pyramid.
Let's see: often some monoliths of the walls, have at the bottom two small growths, probably to be removed later during finishing operations, but this was not done, so still present (photo **N55** and **N56**).
These small bumps had their purpose in the building construction, but in my opinion, they are the result of a special extraction technique.
The pyramid of Menkaure, despite having a smaller size with respect to the next ones, (perhaps the pharaoh was not so young) certainly it is not modest: red granite blocks, for seven rows, covered its lower part.
Remember working this hard stone was terribly challenging, so the finishing of the surfaces has not been completed. One can observe that unfinished blocks often show two bumps along the bottom side (photo N 57).
There must be a relationship, I told myself.

After much consideration, I think I understand.
Some blocks have been obtained by working boulders outside the quarry and those will not have the strange growths, but it is different if extracted from a quarry.
I have read that using wooden wedges, stuck in a long fissure and then wetted, the detachment of the monoliths was achieved.
The method certainly works on the flat, but it seems complicated for the detachment of a block from the substrate.
I think it is possible to do better. For the huge blocks such as obelisks, this method could, if poorly coordinated, induce an unexpected fracture, not to mention the problem of transporting such a huge artifact (the method will be described shortly), but additionally how will be possible to raise the monoliths onto the towing device?
All these processes, in my opinion, use a single ingenious technique.
Imagine the block already detached on all four sides up to the required depth.
We will have to separate it from its base.
One will then start to dig horizontally on the bottom flanks on both sides, but this will soon be interrupted from the upstream side of the quarry, and will continue from the downstream, forming a support rib in lateral position with respect to the centerline of the block.
The masons, engaged in this hard work, will continue to create a large number of holes through the rib, weakening the support.
In the last stage wooden logs will be introduced within these holes and the work will continue from the upstream side, weakening the slender pillars until the spontaneous collapse due to the monolith weight (cause the asymmetry) onto the underlying logs, ready to begin its journey as described below.
I came across old photos on the Internet taken inside the rooms that overlook the Zed (photo **N58**).
I have already said that these large granite monoliths are well finished on three sides, but still having rough the fourth one.
Looking at the photo carefully, you can see the unfinished side crossed by numerous transverse, parallel, well-ground grooves. This seems to be consistent with the explanation given above about the block detachment from the quarry bedrock.
Returning to the Pyramid of Menkaure: for blocks of modest size, just one or two protuberances, to be removed later, might be necessary.

Based on this hypothesis, please have one more look at the bumps seen before and those of the Andean great monoliths (photo **N59**) and it will be clear how it was possible to carry them from the distant quarry.
The " short logs" method can be even further improved by adapting it to bring the great monoliths of the Zed, having at least a smooth side when disembarking from the ships, along the "Path of the Priest": just make many parallel strings of sliding blocks with towing devices, using a double rope.
To be able to go up in this way, however, it will be necessary having the monoliths upside down first, in order to offer the smooth face to slipping, which was facing upwards on the barges.
Overturn the monoliths without making any damage may seem problematic enterprise, considering their weight, but I am convinced that everything was made by partially sink the barges within the port and then reversing the monoliths keeping them suspended by the floats.
Referring again to emerge from under the barges, it would then be able to proceed with the decharge...
The great obelisk of Aswan, abandoned in the quarry from being fractured (photo **N60**), clearly shows that no time was wasted at the quarry: the top side of the monoliths was smoothed while still working for extraction.
The only limitation of this method is the monolith thickness: this will affect the pressure onto the support blocks and thus ultimately the pressure onto the ground, like the hydrostatic pressure that is the product of the specific weight and the height of the liquid column: the specific weight being unchanging, the only variable will be the height...
Some authors have spoken of thousands of men being involved to move one of these monoliths. Let’s check by the new lever system: 50tons with a friction coefficient 0.5 gives us 25000kg, which, divided by 25kg per man, take us to 1000 men. Using the levers with a 4:1 advantage, the pulling crew can be reduced to 250 men (this is an uphill path, but I suppose the levers had a much bigger efficiency).
Each of these giants is about 8m long (wide for transporting) so a double lever may be installed per stone meter.
There will then eight crews at work, so:
250: 8 = approximately 30 workers for each crew, along the same line of about forty meters.
The numbers seem reasonable, and it could also do much better than that.

Probably the same technique was used to transport the three monstrous monoliths of Baalbek (Lebanon) weighing about 1,200tons each.
One of these, however, lies near the temple to the delight of tourists and the damnation of the researchers, unable to explain the method of transport.
The height of this huge block is probably compatible with the maximum tolerable pressure by the ground. An unexpected rain, when transporting, sank it into the quagmire and had to be abandoned (photo **N61**).
Several times I spoke about the dirt ramps to take the smaller blocks up: it is time to say something about too.
Someone made the calculation of the size of a hypothetical ramp placed frontally at a side of the pyramid, but the volume of the ramp was even greater than that of the pyramid itself!
Even a wrap-around ramp, like a corkscrew, is not much better.
There are recent publications showing ramps still more elaborate, all having something unconvincing due to the excessive complexity and, at least in my opinion, none able of running.
I've read that, on the basis of almost two and a half million blocks and twenty years time, even working for twenty-four hours a day, a block every four minutes had to be installed.
Just try, working it out with a calculator.
But the work was carried out only during the daytime. Additionally the working operations had to increase or decrease because, for sure, the floods of the Nile set the number of workers: during flooding many peasants were forced to leave their barracks and move elsewhere.
A job, offered by the pharaoh, was welcome for many people, also avoiding thousands of stragglers crowding the city, engaged in criminal activities.
Finally, I believe, a constant flux of blocks is implausible: the ramp, in the early stages, might allow the transit of over 1000 blocks in a single day, ignoring the delays due to the many accidents certainly occurred; it is unthinkable that the whole work had to stop for any incident, having just a transit route...
A single ramp will never be enough for the transit of all the blocks.
Perhaps at the initial phase a great embankment, connecting the southwest corner to the quarries, might be helpful but, going up, the ridge will be restricted and, in my opinion, inadequate.
The only solution is to have more ramps at the same time.

Before proposing my solution, it is worth going back to the towing method previously described: it has another important advantage of which I show you now. The wraparound ramps, recently proposed, do not solve the problem of the block moving around the pyramid edges. Lift the blocks to rotate them, as I saw recently in a widespread animation, I think, is frankly nonsense...
My towing method lends itself rather to a rapid reversal: just changing the ropes and quickly it will be possible to move the block in the opposite direction!
Keep in mind the towing blocks have a symmetrical shape (at least the one I have invented...)
This kind of inversion is well suited to a multitude of narrow ramps (no more than 5 cubits wide, about 2.5m) made with the honeycomb technique on three sides of the pyramid. Imagine many hexagons, like the cells of a beehive, leaning on three sides of the pyramid, but "crushed" to reduce the working slope. The horizontal part (which is also wider) has precisely the aim of inverting the tow (dis **N62**).

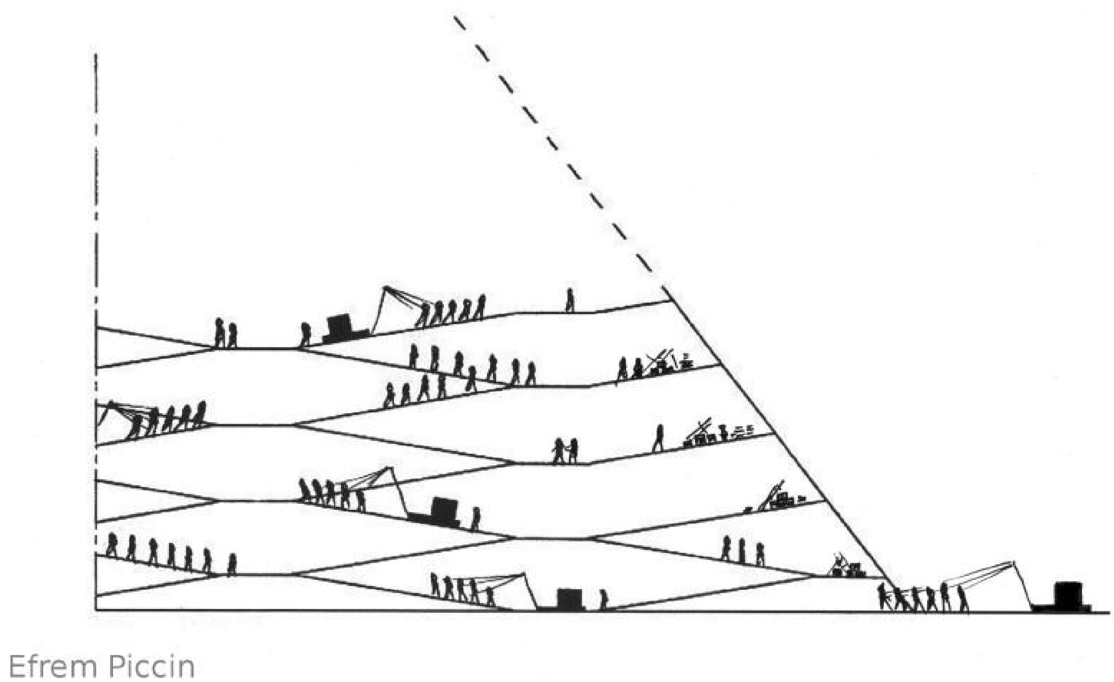

Figure 20: The ramps

In this way the corners of the pyramid remain clear, to check the proper alignment. Another reason to reduce the ramp width is due to the building material widely available on site, namely the wood and leaves of palm trees.

Logs, no more than 5-6m tall and placed vertically, linked to shorter ones transversally resting on the pyramid steps, are suitable for a narrow embankment. The palm leaves, fitted at the side between the vertical stems, hold the soil laterally.
Obviously, going up, the number of ramps will be decreasing, as it is reasonable that it should be.
This is the only way to do.