XIII
The Device

At this point, we should be going back to the Antechamber of the Portcullises to describe the hydraulic mechanism, but since I'm afraid of forgetting the issue of the double vault at the main entrance, I prefer to address it here.
In the previous chapter, I described how, at the legitimate entrance, we can observe two powerful stacked limestone vaults, placed to protect the entrance of the Descending Corridor (photo **F01**).
In his comments, the author of the planimetry in my possession blames the apparent uselessness of the device since the vertical forces acting in this position, so much to the side, do not justify such disproportionate protection.
It might seem like a good argument, but as usual I do not agree.
If Hemiunu designed it in this way, he must have had good reasons, which I hope to uncover.
It is worth mentioning that the entire Grand Gallery and the associated corridors are preserved in perfect condition.
Much more modest cavities in smaller pyramids have however proved to ill bear the burdens above, not only the rooms, but also the corridors and the architraves, so much so that after the erection of Cheops's pyramid they have gone back to building rooms at a very low level or even dug into the rock. Even the construction techniques of our times are not enough: something more is necessary; something that only Hemiunu has been able to conceive.
I will not be surprised then if the architect had the corridors protected superimposing a double vault system along their full length.
There are other good reasons leading me to this hypothesis: the "ventilation" duct that rises from the King's Chamber to the north, bend conspicuously westward for six to seven meters; certainly to avoid intersecting the Grand Gallery, but in actual fact, it starts at a point one meter beyond its west platform. To move laterally so much means, in my opinion, having to avoid something much larger, such as a double vault system like the one we've seen before.
The same thing applies to the north shaft climbing up from the Queen's Chamber: even in this case the deviation to the west is of the same order of magnitude.
Point to note: only the ducts facing north have this anomaly, since those on the south side they have a straight path.

This also supports the hypothesis of a comprehensive project: while building the Queen's Chamber it was already taken into account that the north duct should have to avoid something to be built much later (the Grand Gallery, of course).
Back to the structural analysis, it occurred to me that, starting from the entrance, the double vaults could cover the first part of the Descending Corridor and then, changing direction upwards, the ascending corridor till the Grand Gallery where it would have to rise suddenly and continue to the King's Chamber.
All works out well except for some inconsistencies.
Firstly, such a system is too complicated and may not be as suitable for this purpose as it seems to me.
Secondly, the unnecessary extension of the double vaults to a part of the pyramid virtually free from vertical compression, like Dormion remarks: the architect, even if he had this complicated protection made, should have stopped it long before the entrance to avoid wastage.
Thirdly, studying well the planimetry and the many photos I have, it is possible to pick up details maybe telling a different story.
Imagine that the visible vaults at the entrance are the last two of a sloping path, which had to continue, with a little thicker vault, horizontally to the original entrance destroyed by Al Mamun. A trace of mortar can be seen in the midpoint of the upper vault at a level of 50cm higher than the edge of the bottom vault (photo **F02**).
This seems to be confirmed by the fact that outside the pyramid, on the east side, there are the remains of two of these vaults, broken but of the right size. At the same time, on both sides there are two bases shaped so as to accommodate at least six vaults of this type.
So, from the outside in, there would have been six horizontal vaults, a little bigger, then two stacked vaults; after that... we'll see.
Under the two-stacked vaults there are three grooves on the top of a block, probably carved by Al Mamun to insert some beams during the emptying of the Ascending Corridor (of course this is just my opinion).
Above these three grooves, under the two vaults but set back, there are two barely visible stones laid side by side, with the vertical joint aligned to that of the vaults above, (picture **F03** and **F04**).
This type of symmetry from the structural point of view is dubious: the aligning of the joints is a structural weak point, more reasonable an offset, unless...

I know that only by a drawing or photo you can see how things stand; however it is an important detail.
All these details disagree with my idea of a series of double vaults to protect the descending corridor.
The vaults going to the exit horizontally, instead give the impression that from here begins an uphill path.
The hypothesis seems confirmed by two side by side blocks which can only be explained if they were a kind of double roof placed to hold another series of vaults, laid behind but higher than the visible ones.
However, I was sorrowful, being unable to understand why the system of double vaults was to go up instead of down.
Discouraged, I drew in my planimetry an uphill path using the usual angle of 26.5°, and all was clear.
The vaults so constructed will go straight to cover the Grand Gallery and will end at the two trusses protecting the Zed, exactly at half the height of the pyramid (fig. **F05**).
I also made a fairly good drawing to show it, which I find very convincing (fig. **F06**).

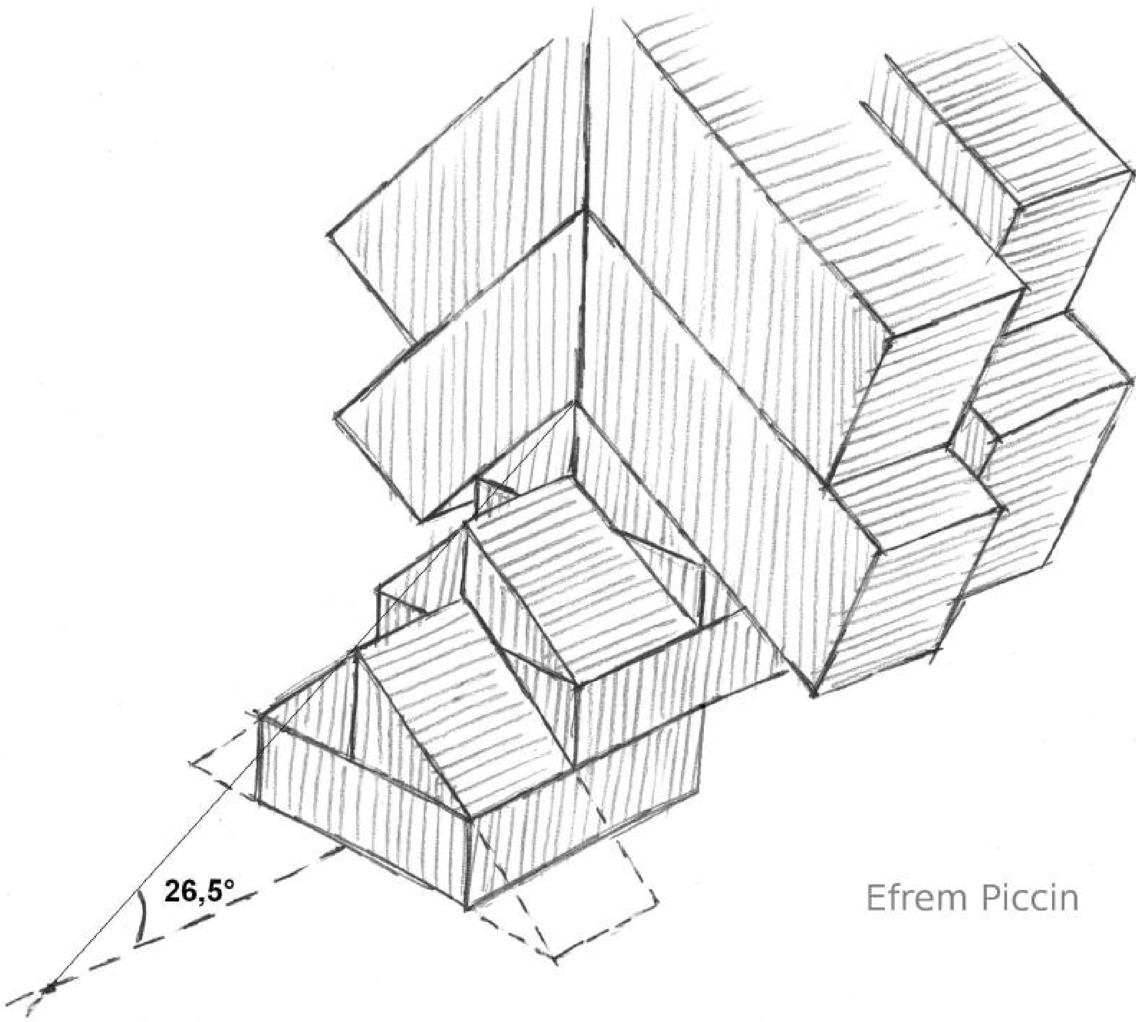

Figure 14: The Double Vault

In my opinion, Hemiunu chose the most intelligent and reliable solution: after all, the part to be protected is the Grand Gallery. The corridors are still much less vulnerable…

At the same time, since each party must "fit" into the previous one, like the pipes of a heater, this vault system starts from the entrance. Which is why, at least from my point of view, everything fits (I'm talking about the overall project, of course).

I know that this is just a guess but, perhaps, checks carried out on site might prove it...

Now let us return to the Antechamber of the Portcullises and let’s talk about the pressurization device.

Then imagine that a perfect hydraulic seal was planned from the design stage already. About that, before to install the portcullises in their homes, Hemiunu inserted a "U" shape copper bracket into the two small holes at the south side of the double-stacked partition (photo **D05**).
The two holes cannot be made in a single horizontal block as the short distance in between may induce, under stress, a fracture; much better to drill them in two separate blocks, vertically placed. The bracket, once the granite portcullises are lowered, will be used to hold a wooden crossbar inserted from the small opening above, as a stop for a proper gasket, made with greased and pressed hemp and more laths, to allow then the rest of the cavity above to be filled by mortar (?...!).
Also the two notches, previously described (photo **D29**) on the sides of the monolith with the grooves, will have a similar purpose, being placed at the same height.
An adequate copper bar will be squeezed transversally to fill the whole space between the first of the granite portcullises and the monolith with the grooves.
The aim still will be to create a suitable stopping point for a whole series of wooden slats alternating greased hemp that will be inserted and pressed from above, filling up the small gap (excluding the grooves, of course) after the portcullises have been lowered and the round head stones installed.
At this point despite the sealing gasket just installed, within the Antechamber of the Portcullises the water may still flow on the floor and between the portcullises and the walls.
Supposing the three blocks with the round heads will be pushed up installed on their supports and sealed by fresh mortar, let's check the work done starting from the block with the grooves. First there is a small hollow space filled by wooden crosspieces and greased hemps, then the first of the three round-headed blocks and a space of two palms (15cm) between the first and second portcullis. The second round-headed block follows and a space of two palms again, then the third block and an empty space of a single palm now (the third guide being narrower).
In this last hollow space the copper bracket has been placed into the two little holes and the gap filled by wooden cross bars and pressed hemps.
Hemiunu will get the hydraulic seal by pouring fresh mortar up to the top in the gaps between the portcullises (which is why are three) and placing three T section blocks: these blocks resting on the round headed ones and inserting the vertical piece of the T into the gaps in between.

The mortar will bond the T stones to those underlying till the double granite divisor to prevent any shift, even minimum, towards the north of the granite covering.
Everything will be sealed in a perfect way, leaving only the four vertical grooves to create a communication between the king's room and the vestibule (and therefore to the Grand Gallery).
The size of the T blocks will be a cubit (52.5cm) wide, three cubits (157.5cm) long and two palms (15cm) thick, having below a central rib each of 2p, 2p, and 1p (15cm, 15cm, and 7.5cm) respectively and deep at least 3p (22.5cm), to enter vertically into the three cavities, drenched in fresh mortar, to firmly hold in position the blocks below.
The ribs will be half a cubit shorter (26.25cm) on the west side, to let the block resting over the three saddles including the top of the three granite guides that are higher on that side.

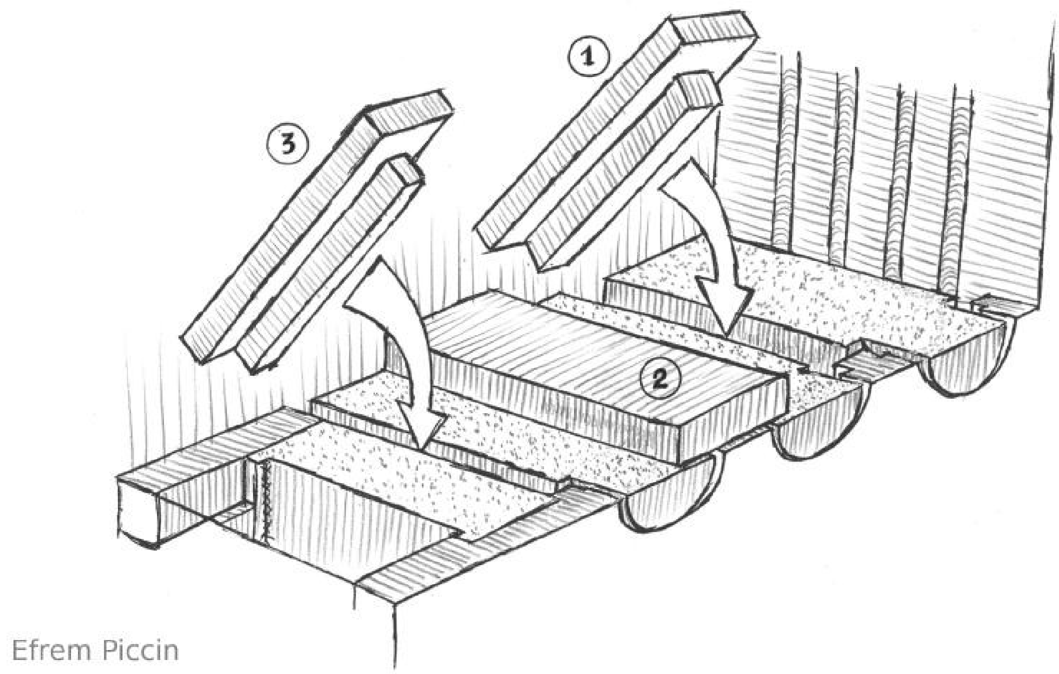

Figure 15: The T-section Blocks

This will help also the block rotations without getting stuck against the ceiling (photo **F10**).
Photo sequence **F07**...**F18** may help for better understanding.

A little more fuss and we’re done: between the T blocks still are two square section gaps of two x two palms (15cm x 15cm) to be filled by two adequate granite stones also mortared to level the whole top cover (photo **F19**, **F20**, **F21**).
This mortar left two square imprints, in the right place and size, visible on both sides (photo sequence **F22**...**F33**).
In **F28** you may even see some granite fragments bonded to the wall.
Perhaps with better pictures, it might be possible to detect also the other two imprints.
Back to the description: everything has been rigorously sealed and there are no leaks of air or water; now the only possible conduit with the King's Chamber is through the four grooves.
The rest is easy: in due time, a man will climb just above the portcullises from the vestibule carrying four suitable semi-circular wooden wedges and will seal the grooves.
Inserting the wedges may transmit stress to the first round-head block so that it could be induced to slip back. It is precisely for this reason that the last T blocks were installed: their vertical ribs fill the spaces between the blocks below, preventing any shift.
It is obvious that the functioning of the hydraulic device will depend on the work of this man, and I like to believe it was Hemiunu in person taking charge of this detail.
A single copper pin (previously installed) connecting the four wedges can help expelling all together, with the adjoining gasket of wooden bars and greased hemps, when the pressure in the King’s Chamber rises.
At this moment the violent water flow required to move down the 25 granite sealing blocks will start (?...!).
It will be a flow of up to 200 liters of water per second, lasting for few minutes!
Finally we understand why the stone with the grooves is made of a single monolith: it is the heart of the device and no leakage could be risked.
Since its integrity is indispensable, it has been protected with every possible precaution, as we have already seen.
From time to time I happen to read what I wrote to check in what manner I can correct it; not being a professional, my penmanship presentation is not very smooth. I hope you will forgive me.
I put myself in the shoes of a willing but skeptical reader: the solution that I propose is frankly unimaginable. It is almost impossible to accept the idea that

there existed 4,500 years ago someone with all the necessary theoretical and technical skills to do that.
Hemiunu had an obvious and extraordinary talent for construction, knew the properties of vectors, and had awareness of the pressure and its effects on fluids. He knew that liquids are incompressible and knew the hydrostatic pressure, but above all he knew how to make accurate calculations. He was not willing to take risks, for any reason. If he had further doubts, he built models and did trial with those...
Too bad that all this knowledge has been lost: perhaps because Hemiunu had no children, having devoted himself to the pyramid, or simply because the time was not right, who knows.
I understand the skepticism, but at least you have to acknowledge that I have been able to settle among them dozens of details according to a single coherent design, good enough to be functional.
If you were to construct a model of all the parts described above, the entire device would work exactly as I have said; that must also be taken into account...
Before continuing, I would like to say a few words more about the Antechamber of the Portcullises and its device.
Often the obvious things become significant only after they have been adequately highlighted.
Let's review then the entire device, imagining that it is a bottle of champagne lying on a plane.
Since the bottle will be pressurized, we will use one of those plastic caps with a knurl and the metal cage that we all know.
In our case, the entire Antechamber of the Portcullises will behave as a cap, where the sealing "gaskets" are the two castings of mortar made between the three shutters. It will be more complicated to prevent the ″cap″ be let off by the action of pressure, which is expected to achieve at least three atmospheres.
The passage leading to the King’s Chamber is 112cm (height) by 105cm (width) for an area of 11760cm^2, so a force equal to 35280kg has to be thwarted!
It is obvious, but worthy of surprise: it is 35tons. This tremendous effort must be countered by an opposite effect distributed among all the parts, which are the three grooves in the side granite walls containing the portcullises, the "cushion" of mortar cast between the third portcullis and the granite divider, as well as the divider itself that will act as the metal cage of the bottle, bearing the bulk of the effort and prevents the stopper from being shot away by the pressure. Please

remember this particular stress distribution, because at that time we will evaluate their effects.
Have patience.
Adding this very note in retrospect: it is March 09, and there is no word regarding publishing of the book...
I re-read this part with an eye on the wooden model I built and the pictures I have.
In particular I was looking at the repair carried out in recent times above the semicircular bump carved onto the granite divider I have already spoken (photo **F34**): having the shape of a figure eight lying horizontally, it is perfectly compatible with the damages caused to the divider surface when the blocks were being handled within the vestibule, dropping down to rest on the bump in safety conditions.
In my hypothesis I supposed all the blocks (and I considered only the six largest) climbed over the divider from the west side, although the marks tell me that, of course, the east side was involved as well, and not a little.
Returning to the model and moving my "blocks," I realized that the blocks with the vertical ribs must be lifted up leaning against the west wall only. On the other side there is no space enough to the ceiling to rotate them.
That means the round head blocks have rested on the east side of the button.
On closer inspection this means that picking up the first three blocks on this side, it will reduce the wearing out on the west side of the bump, certainly earmarked for the last three.
Secondly, it might be easier, after having rotated the round head against the southeast corner, to place the block in a vertical position being supported on the east side of the corridor and not, as I said at the beginning, held against the west wall. Now raising the block from this location, we could lay it on the bump from the east side and then taking advantage from the semicircular (obviously not by chance) shape to tilt it gently on the other side and then lift it up by the method previously described (photo sequence **F35**...**F41**).
More and more I think about it the second way seems less tiring... not forgetting it also preserves the bump integrity from the other side, which is essential to complete the job.
We explain finally how an energetic flow of water could free the 25 granite blocks placed inside the Grand Gallery.

I want to remember this is only a theoretical project, a plan that maybe Hemiunu had long cherished before surrendering to the difficulties about the ascent of the blocks inside the Grand Gallery...
As usual, you must arm yourself with patience and good will because it is not a simple thing. Indeed, while enjoying understanding, I had to work hard.
Imagine the 25 blocks placed in the groove between the two platforms, hold by the insertion of wooden wedges laterally, between the blocks themselves and the platforms.
The blocks must be close to each other, better be in contact: it is important that there should be no significant gaps.
When everything will be ready, before the hydraulic mechanism setting up, it will be necessary to empty all niches removing the limestone pillars that have hitherto occupied them.
This is the reason why a poor coarse mortar was used to fill these niches, and the bad quality of the stones inserted: the important things were just the cavities!
Earlier, having to squeeze the pulley yokes against the walls, it was necessary to have a lateral gripping surface as big as possible, for which the cavities had to be filled.
Recall to increase the lateral grip of the yokes, rectangular chips was made on the surface areas above the niches. This due to unforeseen difficulties as explained in the description of the Grand Gallery.
The niches, which have now been freed, will be used to accommodate the ingenious beam systems to keep the blocks laterally compressed, using wedges arranged in a very particular (and risky...) manner.
It is necessary to talk about the measurements of the niches, expressing them in local units (palms and cubits).
I hope the shape of the niches is well known: they are vertical trapezoids having the bottom side parallel to the platform slope and at the same level (photo **C03**, **C04**, **C05**).
The long vertical side measures 60cm (8 palms, or 1 cubit + 1 palm); the short is 48cm high (measurement not standardizable), while they are carved half a cubit (27cm) inside the wall.
Returning to the working procedure: the locking side wedges would have to come unthreaded only just before the hydraulic device starts working, leaving the ultimate security to a control system realized by two series of lateral (right and left) wooden beams, even acting like dams, inserted into the niches (so centrally located

with respect to the blocks) and compressed against the blocks by special shape wedges.
These were very long, like poles, and trapped between the dam beams and the block, inserted from the upstream side of the dam itself, nearly in a vertical position, sticking out above the platform plane (photo **F65**).
The violent hydraulic flow, triggered by the expulsion of the wooden caps inserted into the grooves, will overwhelm the long wedges, causing them to rotate, plucking up their position and finally freeing the convoy of the sealing blocks.
The flow would hit head-on the first of the blocks, placed close to the big step, giving a formidable thrust continued for several minutes.
Very turbulent cascades would be formed on the sides that would generate a powerful dragging effect on the block flanks while passing over the wooden dams and, finally, the presence of water would greatly decrease the frictional coefficient and thus the value of the friction itself.
Under these conditions, I consider the convoy will certainly move. I plan on carrying out a test with my wooden model to prove it, but using instead of water a cascade of small glass beads...
I hope to have satisfactory results and hope to show you a short video.
I will briefly describe here the side dams, because their implementation has required a long planning (at least on my part...).
I imagined then that each dam was made of some wooden beams.
The first beam, the one resting on the platform, should have a trapezoidal section to ensure the sealing from underneath. I fixed then the angle as 26.5°, the greater height as 4 palms (30cm), the width as 3 palms (22.5cm) and the length, crossing the platform, as 75cm (1 cubit + 3 palms) from the side of the block to the back of the niche.
In this way, the beam is not right stuck into the niche, having a lateral gap (along the north-south axis) equal to almost 4cm.
This is the difference between the width of the niche (half a cubit = 26.25cm) and the beam that I fixed as 3 palms (22.5cm). The two measurements are "standardized" and their difference corresponds to half a palm = 3.75cm.
By using a 1:10 scale model I worked hard to see if I could fit in place this wooden beam. If the piece had just square ends, it could not perform the necessary rotations to fit in position. I started then to remove the material in excess, though fearful to lose the water sealing on its perimeter.

Finally, working with patience I was able to put the beam in position following a complicate rotation (the niches have, quite rightly, the highest and the north edge smoothly beveled, a "by design" job...).
Wonder of wonders: the final shape can assure the complete sealing all along its perimeter. There will always and everywhere be a lateral contact!
Very much emboldened, I figured it was enough to repeat the process with the second beam: but no, at the time of its insertion, after the necessary small ablations, the final shape was no longer able to ensure no leakage.
Now I know that the solution was simple, but for a moment I feared the worst.
The solution is to complete the work using two prismatic beams, each 2 palms (15cm) thick, three palms (22.5cm) wide, and still 1 cubit + 3 palms (75cm) long.
A modest machining of two end corners was sufficient, having already the niche edges beveled, by rotating, to put the first one in position.
The top one also needed a similar processing but I was already accustomed.
In particular, in order to insert the third and last beam in place, the rotation was made only on the horizontal plane, to occupy all the available space in height within the niche. In this case, it was not necessary to taper the upper horizontal edge of the cavity.
By checking the finished work, I observed that each of the three beams needed removal of material, but it is not a complicated job since it was always from planar faces. Of course it is necessary to know exactly the area to be modified, but made for a series, what applies to one applies to all (photo **F41**).
Hemiunu, as a good engineer, was certainly a great planner of his work.
This is not the only case of pieces worked in series much before their installation.
Imagine the three shaped beams inserted in place (the same operations will obviously carried out on the other side of the block with a “mirror image” of the beams): there will be just a little gap at the block side, but we know that we still have to insert the sealing wedges.
Now the three beams of the dams have to be moved forward south. There is a lateral gap of 4cm almost. So the beams may be pushed a little higher, but just a little because they will inevitably be stuck, since the niche height is diminishing: exactly what I think Hemiunu had in mind to get a good block arrest and the hydraulic seal.
Imagine all the dams installed on the sides (right-and left) of the blocks.
Before inserting the new wedges, wooden rectangular plugs have to be placed vertically inside the two pits, placed one in front and one behind each dam, to fill

the empty spaces on the floor of the platform, keeping the dams in position and discouraging any water flow through the pits which might act as siphons...

The new wedges will be very long and installed south side of the dam, to be freed by the hydraulic flow and let the blocks to slide down. The safety wedges, previously placed, have to be removed just before the pouring of the water into the ducts.

So from this moment on, the blocks will be held only by the long wedges stuck between the dam and the block...

Needless to say the safety is at a minimum (photo sequence **F43**...**F65**).

Please remember we can expect a hydraulic flow of 200 liters per second for the duration of few minutes and the slope is severe (more than 26 °).

If everything had been carried out correctly, the device had a high probability to work properly. I will test it in my model (of course, within the limits of the simulation).

If...

But I remind you that there were only three blocks on site, and the niches have been found filled; so although the hydraulic device was successfully activated, certainly something in the final stages did not go the right way, but we'll see... (?...!).

I hope the logic of my explanation will convince you. Let me point out that this part could be reconstructed with the same measurements, the same forms, and be operational.

I will check it in the wooden model I'm building (June 2008), by pouring a cascade of small glass beads.

I am very optimistic about it.

We'll see (photo sequence **F66**...**F80**).