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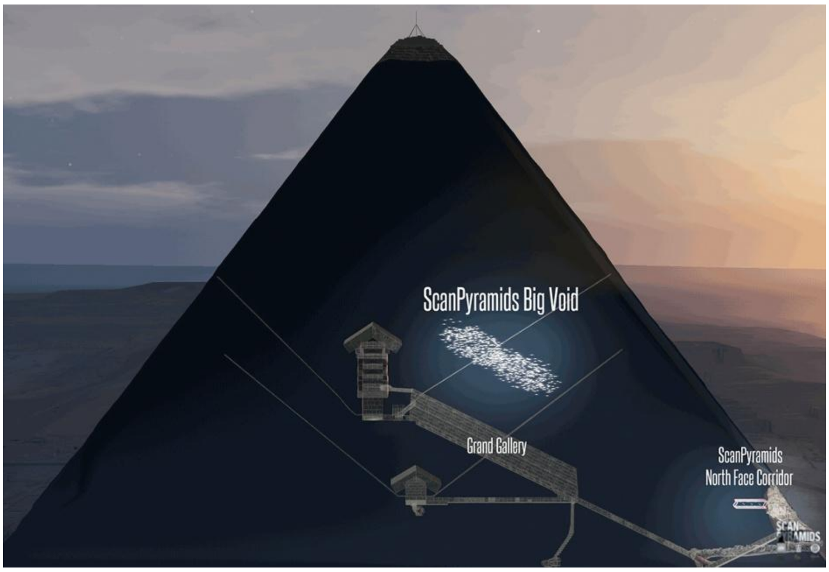
Khufu's Pyramid,
recent discovery of a large cavity by the ScanPyramids mission

This important void, designed by Hemiunu and Ankh-Haf, is essential to the construction of the structure above the King's Chamber.



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The Big Void

Memoir

This text is part of a future trilogy and will be followed by :
"Khufu's Pyramid,
recent discovery of a corridor under the North face by the ScanPyramids mission"
and then by
"Khufu's Pyramid,
recent discovery of a cavity under the northeastern edge by the ScanPyramids mission".

PARIS,
10/25/2022

(English translation by the Author)

TABLE OF CONTENTS

RECOMMENDATION

Many of the illustrations in the document are small in size in order to limit the number of pages. For a better reading, it is recommended to display the Pdf pages on your screen at +150%.

To HRH…

1 - PREAMBLE

Following the intuition of my father Henri Houdin (engineer of the Arts et Métiers, Paris 1941[1]) in early January 1999: Khufu's Pyramid was built "from the inside" partly thanks to an internal ramp, I did not cease devoting myself[2] to the resolution of this more than 4.500 years old enigma. Since almost a quarter of a century I'm immersed in Khufu's Pyramid, and its Egyptian counterparts, particularly those of the fourth Dynasty.

From the beginning, I understood that I had to think as an "Egyptian architect of the time" and not as a builder of today; so I had to acquire the maximum of knowledge about the techniques, materials, tools and know-how available to the ancient Egyptians of the fourth Dynasty.

Between 1999 and 2005, I spent more than 5,000 hours, alone, modeling my ideas in 3D[3] , with the unique advantage of being able to visualize, in real time, what came to my mind, with the ability of knowing precisely the spatial relationships of the different elements I had in front of me on the computer screen.

In March 2001, I was already fully convinced that the architects had imagined the project designing two distinct building sites integrated one into the other: on the one hand the volume itself, on the other the King's Chamber and its superstructure; these had then been realized with completely different methods and means, each one being optimized for a perfect execution.

In 2003, under the impulse of my father, the Association Construire la Grande Pyramide[4] was formed by a score of engineers and scientists[5] , its goal: "...to *gather the scientific, technical and financial means to be implemented to support the development and the recognition of the above mentioned theory and to study the internal structure of the large smooth pyramids of the fourth Dynasty on the example of Khufu's Pyramid. It will focus in particular on the detection of still unknown cavities".*

From 2004, thanks to the help of the ACGP and its patrons[6], I was able to go regularly to Egypt and to make my own investigations on spot; I often found a clue which came corroborating one of my proposals.

Thereafter, thanks to a remarkable collaboration with Dassault Systèmes[7] started in 2006[8] and the 3D design and virtual reality software[9] of this company, the "knowledge" of the interior of Khufu's Pyramid made an incredible leap forward, allowing, in addition, to carry out heavy operative simulations on

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[1] Ecole des Arts et Métiers, Paris.
[2] And that was with him until his death on October 25, 2014.
[3] With AutoCad software.
[4] ACGP, Association Construire la Grande Pyramide - www.construire-la-grande-pyramide.org.
Currently, Laurent Chapus is the President, Jean Billard the General Secretary and Chantal Mazières the Treasurer. Laurent Chapus is also the Treasurer of HIP.Institute.
[5] Many of them are members of the Committee of Experts in Construction of the CNISF - Conseil National des Ingénieurs et Scientifiques de France (now IESF) and Mrs. Ruth Schumann-Antelme, Egyptologist, former assistant of Mrs. Christiane Desroches-Noblecourt.
[6] Eiffel Construction Métallique, THALES, Gaz de France being the first.
[7] A world leader in 3D design software headed by Bernard Charlès.
[8] As part of the "*Passion for Innovation*" sponsorship program led by Mehdi Tayoubi assisted by Richard Breitner under supervison by Pascal Daloz. I was introduced to Dassault Systèmes thanks to Jean-Jacques Urban-Galindo, who was present at a conference given at the Société des Ingénieurs des Arts & Métiers at the invitation of Gérard Ledieu, Hubert Labonne, Jean Carayon, Pierre Jartoux, Jean-Louis Simonneau and Vincent Guittet. The solidarity of the Gad'zarts for one of their comrades, my father Henri.
[9] CATIA, DELMIA, SIMULIA and VIRTOOLS. These softwares have contributed to the impressive development of my work, with the help at my side, among others, of two specialists, Jacques Jaworski and Alain Dugousset.

many technical aspects of this building site. After all these years, I have, I humbly confess, acquired an extraordinary ability to "connect the dots" between all the components inside Khufu's Pyramid. This knowledge has been extended to the whole Giza Plateau, the implantation of Khufu's Pyramid being the first great success of the project.

Last element very important to understand my state of mind in my work on the pyramid: I always tried to make my proposals evolve, as I progressed, with the focus on "logic and simplicity", which for me were fundamental in the design and construction of the Great Pyramid.

In history, two geniuses have been followers of simplicity:

- Leonardo da Vinci: "Simplicity is the ultimate sophistication".
- Albert Einstein: "The supreme objective of any theory is to make the basic irreducible elements as simple and reduced as possible".

I am absolutely convinced that Hemiunu and Ankh-haf, the architects-engineers who designed and built the Great Pyramid, were geniuses animated by the same spirit as these two great men.

2 - GENESIS OF THE SCANPYRAMIDS MISSION

The origin of the ScanPyramids mission goes back to March 21, 2002, the day when my father and I met, at our request, the Cultural Counselor of the Egyptian Embassy in Paris, Professor Hany Helal. The latter opened the door to Egypt, the same year by programming, with Dr Mahmoud Ismail, my very first lecture at the Egyptian Cultural Center in Paris, then, in 2004, by introducing me to the General Secretary[10] of the Supreme Council of Antiquities (SCA) at the time; finally and above all by committing himself to help me set up a scientific mission.

Thus, at the beginning of 2005, Hany Helal being back to the Faculty of Engineering in Cairo, the ACGP and the ECAE[11] started to work on an investigation mission project on Khufu's Pyramid by means of non-destructive techniques which would be selected among a dozen disciplines.

With the help of my friend Egyptologist Dr. Bob Brier[12] and after more than a year of preparation, a very comprehensive file was ready to be submitted to the SCA. It was to be filed in the name of the ECAE and the CNISF[13], with financial support from the ACGP, under my direction and with the participation in residence of Professor Hany Helal. The mission project was based on three priority non-destructive techniques, microgravimetry[14], reflectometry radar[15] and ground penetrating radar[16];

[10] Dr. Zahi Hawass.
[11] ECAE - Engineering Center for Archaeology and Environment. Faculty organization, headed by Mrs. Nahed Abdel Raheem, which prepared the restoration programs of the monuments for the SCA.
[12] I met him in New York in June 2003 and he has been involved with me since our first meeting. Bob Brier is nicknamed "Mr. Mummy" for having mummified a corpse using Egyptian methods.
[13] CNISF - Conseil National des Ingénieurs et Scientifiques de France (now IESF).
[14] SAFEGE company, ex CPGF company having carried out the microgravimetry campaign in the years 1986/87.
[15] For the project, the THALES company carried out two test campaigns on the Castle of Coucy (Aisne) and that of Pierrefonds (Oise). François Levieux, President of the Scientific and Technical Committee of the ACGP, was at the time the director of the technical processes at THALES.
[16] LERM company, specialist in the detection of cavities in the ground with a great experience acquired during the construction of TGV lines by the SNCF.

and given their easy implementation, two other techniques were also planned: infrared[17] and architectural photogrammetry[18].

At the last moment, while I was in Cairo, the General Secretary of the SCA imposed an additional condition: the mission had to include a renowned Egyptologist having already worked on an excavation in Egypt. I immediately thought about Dr. Dieter Arnold[19] whom I had met the previous year with Bob Brier in his office at the Metropolitan Museum in New York to present my work. Knowing that he was at Dahshur excavating the pyramid of Sesostris III, I contacted him to ask if he could receive me. The next day I was on spot explaining him the situation. At the end of the meeting, he gave me his agreement and prepared a letter in this sense that I brought some days later to the SCA. To be on the safe side, I also contacted Prof. Dr. Rainer Stadelmann[20], to whom I had given a presentation of my work a few months earlier and who had been very interested in my ideas. I asked him if he would agree to be part of the mission. His answer was positive and he also prepared a letter for the SCA. With two renowned Egyptologists agreeing to be part of the mission as advisors, I was therefore very confident about the future.

Unfortunately, a few weeks later Dr. Dieter Arnold informed me, with apologies, that it was "impossible" for him to be part of the mission, followed shortly by Prof. Dr. Rainer Stadelmann who also had to "give up"; the double response to the condition for authorization had just been rejected. I learned later that these two Egyptologists had been rejected on the pretext that they both had a mission in progress...

A proposal made by Bob Brier to take the direction of the mission himself was refused on the grounds that he was not a specialist in Egyptian monuments. As a last attempt, I proposed to Dr. Zahi Hawass[21] to take the direction of the mission himself; he declined, telling me that it was not "his" mission. I finally understood that I would never get it from the SCA. A great lesson that I will never forget. That being said, a wise man is worth two...

Then two major events took place thanks to Dassault Systèmes: the "Khufu Revealed[22]" presentation at the Géode in Paris on March 30, 2007, which made my work known throughout the world in twenty-four hours; and then the "Khufu Reborn[23]" presentation, again at the Géode, on January 27, 2011. Between both, I had the privilege of being part of three documentaries about my work for major television channels: "Khufu Revealed[24]", "Unlocking the Great Pyramid[25]" and "Khufu" for NHK Japan[26]; the latter, programmed in "prime time" during its first broadcast on July 5, 2009, will be watched by eleven million viewers. Almost three years later, it will have unexpected but extraordinary fallout.

[17] TCC company - Jean-Claude Barré, infrared expert having acquired a great experience during large projects. Later, he will be part of the infrared team in the ScanPyramids mission.
[18] Professor Pierre Grussenmeyer - INSA Strasbourg.
[19] Egyptologist, at the time Director of the Department of Egyptian Antiquities at the Metropolitan Museum of New York and of the American mission to the pyramid of Sesostris III at Dahshur.
[20] Egyptologist, at the time Director of the German Institute of Archaeology in Cairo and of the German mission to the Bent Pyramid in Dahshur.
[21] At the same time, Dr. Zahi Hawass had just written a preface for my book "The Secret of the Construction of the Great Pyramid".
[22] A 3D presentation in real time and 3D projected on a 400m2 hemispheric screen with animations created by the talented team of EMISSIVE, a start-up created by Emmanuel Guerriero and Fabien Barati.
[23] A new presentation of the same type to announce the probable existence of unknown voids in Khufu's Pyramid.
[24] "Khufu Revealed" directed by Florence Tran for France 2 and France 5 and produced by Gédéon Programmes.
[25] "Unlocking the Great Pyramid" directed by Peter Spry-Leverton for the National Geographic Channel (USA).
[26] NHK Japan - the big Japanese public channel.

Unfortunately again, the January 27, 2011 "Khufu Reborn" presentation took place at the same time as Egypt was entering a difficult period, putting a stop for more than two years to any activity related to the pyramids.

But as the saying goes: twenty times on the loom hand over your work...

That said, between the two events at the Géode, I was contacted in June 2010 by Matthieu Klein, infrared specialist at MIVIM[27]. He suggested to me a partnership for a future mission on the Great Pyramid. After several months of discussions, an agreement in this sense was announced during the presentation of "Khufu Reborn".

In November 2011, I was again contacted by a scientist, Dr. Hiroyuki Tanaka of the University of Tokyo[28] , who, having discovered my work through the NHK documentary, told me that he was a muons specialist and that he could "see" through volcanoes. He suggested to use this technique to "see" through Khufu's Pyramid. In June 2012, at his invitation, I went to Tokyo to visit his laboratory and discuss a mission project. I came back to Paris enthusiastically but the time was still not ready to talk about a mission with my friends from the Khufu team at Dassault Systèmes.

Finally, by the end of 2012, I had gathered three specialists in non-destructive techniques for a new mission project: two for infrared thermography, the MIVIM of Laval University in Quebec City and Jean-Claude Barré (who was already part of the 2006 mission project) and for muography[29] , Prof. Tanaka of Tokyo University.

In February 2013, I reconnected[30] with Hany Helal who agreed to the idea of a new mission project. Due to the political situation in Egypt, we were aware that it would take a lot of time and patience to eventually reach an agreement.

In early March 2014, Dr. Tanaka informed me that the Japanese NHK was ready to fund a muons radiography mission on Khufu's Pyramid and that representatives from this channel were keen on to meet me in Paris to discuss cooperation. This meeting took place on the 24th[31], followed by a second one on the 26th with Hany Helal[32] and the Khufu team[33] at Dassault Systèmes. A few days later, NHK announced that they had agreed to join the mission project we were preparing and that Takumi Hisaizumi[34] was appointed as the project coordinator for NHK.

Shortly after, Dr. Tanaka became unavailable due to other commitments, and on his advice, NHK turned to Professor Kunihiro Morishima of Nagoya University[35] and his team and Professor Fumihiko Takasaki of KEK[36] and his team, each with their own muons radiography technique.

After several months of simulations on pyramid models, both techniques were validated; on November 12, Hany Helal met the Minister of Antiquities, Dr. Mamdouh Mohamed Eldamaty[37] and on

[27] MIVIM, a laboratory of Laval University in Quebec City, Canada Research Chair in Infrared Vision and Thermography directed by Professor Xavier Maldague.
[28] Earthquake Research Institute - The University of Tokyo - Muons Detector Technique.
[29] Radiography by muons, calledMuography.
[30] Through Florence Tran, who was a frequent visitor to Cairo.
[31] With Toshihide Yabuki, Koichi Jo and Ms. Mutsumi Funato (translator).
[32] And Yasser Elshayeb, director of the Egyptian cultural organization Cultnat.
[33] Mehdi Tayoubi, Richard Breitner, Benoît Marini, Alain Dugousset and Ms. Marie-Pierre Aulas.
[34]Takumi Hisaizumi will coordinate with the Japanese teams for the duration of the mission.
[35] Institute of Advanced Research, Nagoya University - Emulsion plates.
[36] Institute of Particle and Nuclear Studies, KEK, High Energy Accelerator Research Organization - Scintilator
[37] Appointed new Minister of Antiquities on June 17, 2014, replacing Mr. Mohamed Ibrahim Ali al-Sayed.

February 10, 2015 the mission project was presented to the Permanent Committee of Egyptian Antiquities. The latter quickly gave its agreement in principle to the mission by dividing it into two phases: the first on the pyramids of Dahshur and in case of positive results, the second on Khufu's Pyramid. Last work remaining: we had to prepare the final mission file which was to be jointly submitted, on the French side, by a non-commercial entity and for the Egyptian side, by the Faculty of Engineers of Cairo, the future "International" mission being placed under the authority of the Ministry of Antiquities of the Arab Republic of Egypt.

On June 7, Dr. Mamdouh Mohamed Eldamaty confirmed in a letter to Professor Hany Helal that the Permanent Committee of Egyptian Antiquities had given its approval to the selected techniques[38] and invited him to transmit the list of equipment used, the CVs of the teams members and their passports for the security services.

On June 8, the association HERITAGE, INNOVATION, PRESERVATION INSTITUTE was administratively[39] formed during a constitutive general assembly gathering the eight administrators[40] , the statutes being signed by the President, Mehdi Tayoubi, and the General Secretary, Jean-Pierre Houdin, the association opting for its designation the acronym HIP.Institute[41] .

The following months were dedicated to consolidating the financing of the mission[42], to scouting on site and to preparations on the logistical side[43] , with the first materials starting to be transferred to Cairo in early September.

Finally, after intense negotiations on the details[44] of the future course of the mission at the level of relations between the Ministry of Antiquities, the coordinators and the operators, the ScanPyramids mission was officially launched on October 25, 2015 during a large press conference held at the Mena House, a mythical hotel facing Khufu's Pyramid; this was attended by the Minister of Antiquities, Dr. Mamdouh Mohamed Eldamaty, Professor Hany Helal, Mehdi Tayoubi, Dr. Kunihiro Morishima, Professor Fumihiko Takasaki, Matthieu Klein and several members of the teams that were going to carry out the mission. The first sentence of the press release of the Ministry of Antiquities was the following:

"*The ScanPyramids project was approved by the permanent committee at the antiquities ministry and has obtained all the necessary permission from security agencies and other concerned authorities*".

The only drawback...The mission had obtained its authorizations[45] under the condition of being "agnostic[46] " and that the data of the possible discoveries being put at the disposal of the researchers for free[47]. Consequence for me: I was deprived of participating[48] in the mission because of my work on

[38] Infrared Thermography, Muon radiography, Laser scanning and Photogrammetry for 3D reconstruction.
[39] The Association had been in preparation for several months and only needed the agreement in principle of the Minister to finalize its creation.
[40] Messrs. Mehdi Tayoubi (President), Jean-Pierre Houdin (General Secretary), Laurent Chapus (Treasurer), Hany Helal, François Shuiten, Henri Pomeranc, Philippe Forestier and Mrs. Laure Kaltenbach.
[41] And also the acronyms H.I.P. Institute or H.I.P. Institute.
[42] The Japanese part is provided by NHK Japan, the rest being taken care of by HIP.Institute thanks to sponsorship.
[43] This one was entrusted to Vincent Steiger, who is accustomed working on films shot on extremely difficult sites, while Nicolas Sérikoff seconded Mehdi Tayoubi throughout the mission.
[44] Being under the authority of the Ministry of Antiquities of the Arab Republic of Egypt, a mission of this magnitude entailed a multitude of legal problems to be settled in advance between all the protagonists.
[45] To advise him in his analysis of the techniques, the Permanent Committee of Antiquities had created a Scientific Council and appointed Dr. Zahi Hawass as its director.
[46] The mission could not be performed as part of an audit of any theory.
[47] The goal of the ScanPyramids mission being to advance the knowledge of the pyramids, this clause was essential because it opened the door to any researcher interested by the possible discoveries.
[48] Small consolation, the date of October 25 marked the first anniversary of my father's death; without him and his intuition of January 2, 1999, this ScanPyramids mission would never have been born!

Khufu's Pyramid and I will not appear in any document published by ScanPyramids. Following my experience of the 2006 aborted mission, I had no difficulty in accepting because I knew that, although remaining in Paris, I would still be at the heart of the mission in real time, being in permanent contact with all the participants. For me, the most important thing was that this mission exists and that the non-destructive investigation techniques on which I had spent so much time would eventually lead to discoveries. As I have so often said during my conferences, "*the stones speak and it is the pyramid that will bring us the answers*". The pyramid did not disappoint me in this respect.

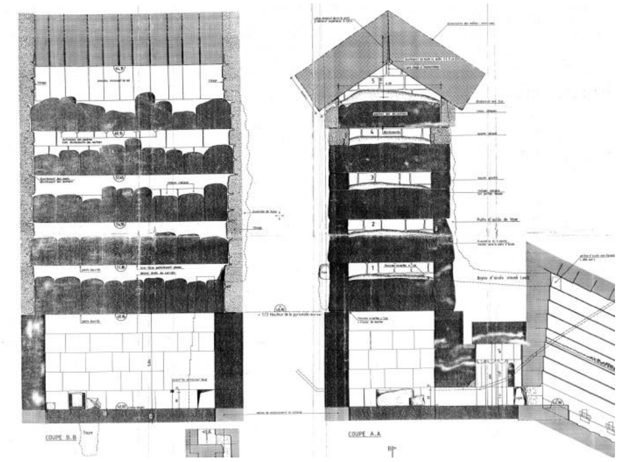
Finally, the success of the mission owes much to Professor Hany Helal and Mehdi Tayoubi who had the patience, resilience and tenacity to carry out this extraordinary undertaking. The three major discoveries announced by ScanPyramids, the Big Void, the corridor behind the rafters on the North face entrance sinking into the body of the pyramid and the cavity detected under the northeastern edge are all related[49] to some elements of my global theory. These discoveries are obviously to be credited to all the scientists and all the participants of this mission whose consequences for the knowledge of Khufu's Pyramid have not yet been really appreciated.

Being part of this project in the background and due to the amount of data gathered during the course of the project, I have acquired a great deal of knowledge regarding the file and it seems to me very legitimate to speak about the discoveries announced by ScanPyramids and to give my interpretation of the Big Void on a very solid basis.

3 - THE PROBLEM OF THE CONSTRUCTION SITE OF THE KING'S CHAMBER

"A problem without a solution is a problem badly posed" Albert Einstein

In the fourth paragraph of the Preamble, I wrote...*"I was already fully convinced that the architects had imagined the project designing two distinct building sites integrated one into the other: on the one hand the volume itself, on the other the King's Chamber and its superstructure".*



Sectional drawings by Gilles Dormion

The King's Chamber and its superstructure
In Aswan granite: Floor, fifty-five square meters, walls, a hundred blocks, ceilings, 43 beams of 25 to 60 tons.
In Turah limestone: Roof, 22 beams forming 11 pairs of rafters.

[49] The Big Void with the counterweight system, the corridor with the Noble Circuit and the cavity with the internal ramp.

The subject of this document is the second construction site mentioned in this sentence, that of *the King's Chamber and its superstructure*, which in my opinion is a masterpiece of design and engineering that needs being sent back in time, 45 centuries ago; for me, as an architect, that makes the feat even more impressive. To understand what will follow in the coming pages, one must first try to "set the problem well"; in fact, everyone talk about a chamber[50] made of granite with perfect dimensions[51], a flat ceiling in defiance of the mass that overhangs it, five other very low "chambers"[52], the first four[53] also with flat "ceilings" in granite and the fifth covered with a roof[54] made of Turah limestone beams forming rafters. As for its construction, nothing, except that the granite beams and blocks were quarried in Aswan, that the limestone rafters came from Turah, on the eastern bank of the Nile, and that they were transported by boat[55] to Giza. Apart from that, it has been said that the monoliths[56] were brought into the pyramid enclosure at the beginning of the construction site[57] and that they were then raised[58] as the construction progressed; a non-solution forgetting practically all the parameters that came into play for this construction site. This is a perfect example of a "badly posed problem".

This list, which is not exhaustive, is an example of the parameters to be taken into account in order to properly pose the problem and end with a solution.

1 - The extraction and shaping of the granite beams and blocks from the Aswan quarries and the limestone rafters from Turah were difficult operations involving many years of effort before all these monoliths being delivered to the site in Giza.
2 - The Turah quarries were about thirty kilometers from Giza on the eastern bank of the Nile, those of Aswan about eight hundred kilometers to the south. From Aswan, transport by boat was done seasonally, during the Nile flood, limiting the number of annual rotations[59] .
3 - In preparation for the construction of the pyramid, a canal connected to the Nile some thirty kilometers south of Giza and a port for unloading materials at the foot of the pyramid had to be dug, requiring between one and two years of work before the first delivery.
4 - The deliveries arrived at the port at the level of (elevation 20)[60] while the base of the pyramid is located at (elevation 60), that is to say a difference of levels of 40m.
5 - All the beams and rafters had to be placed in the pyramid between the levels +49m, (elevation 109), and +62m, (elevation 122), i.e. a difference in level of 102m with respect to the port.
6 - The distance between the port and the South face of the pyramid was about 400m.
7 - At that time the Egyptians had no technical means to transfer by lifting beams and rafters weighing from 25 to 60 tons[61] on a height of 102m over a distance of 400m.
8 - The only solution was to hoist these beams and rafters by towing them on ramps.

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[50] Floor, walls and five "ceilings".
[51] Reference to the golden ratio that its dimensions transcribe and which seems to me founded.
[52] Named after Davidson, Wellington, Nelson, Lady Arbuthnot and Campbell as they were discovered.
[53] The term "relieving chambers" is totally inappropriate because this structure does not relieve anything with regard to the King's Chamber.
[54] It is the only one that takes all the load above; see the document "- *A Computer Simulation to Determine When the Beams in the King's Chamber of the Great Pyramid Cracked"* . https://independent.academia.edu/JeanPierreHoudin .
[55] After being pulled to the Nile, on a downward slope, an easy operation, the quarries being at a higher level compared to the river.
[56] Term that covers all the beams and blocks in granite or Turah limestone of the King's Chamber and its superstructure.
[57] It would have taken about 30 boats capable of carrying up to 60 tons to transport the 3,500 tons of granite and 600 tons of limestone to be delivered in two or three years.
[58] No explanation is given for this although there are still more than sixty meters in height to be reached for the highest chambers.
[59] It can be estimated that two large barges capable of carrying 60 tons and making two rotations each per year over a dozen years would have been sufficient to ensure all the deliveries.
[60] In reference to the geographical level of Egypt.
[61] The hoisting and placing process had to have the capacity to handle the heaviest monolith, a granite beam of 1st ceiling weighing about 60t. Therefore all other monoliths were within the capacity of the process.

9 - Human force not being infinitely multipliable, the idea of employing and coordinating 600 men to pull a beam is absolutely inconceivable.
10 - In order to respect the schedule set by the architects, all the materials used in the King's Chamber and its superstructure had to be delivered to the construction site when the pyramid reached the base of the Chamber at the level +43m, i.e. around the 14th year of Khufu's reign. The designers had thus given the quarrymen enough time to provide perfectly cut beams, rafters and blocks.

The King's Chamber and its superstructure were finally built, indisputable proof that the Egyptian designers had properly posed the problem and that they were confident in the solution they had envisaged for the delivery and placement of the materials: a dozen years after the actual start of the work, they had no right to make mistakes.

That said, the Egyptians were familiar with the laws of physics having utilitarian applications in their daily lives, such as the shaduf[62]; they were likewise familiar with the concept of the scales for weighing the heart[63] of the deceased.

The solution they applied to the site had a name: Counterweight.

But by defining a whole system based on the principle of counterweight which would be implemented relying on logic, Art of measure, programming and planning of tasks, time management, logistics, operations in sequences, economy of means, division of forces at stake, efficiency, minimal use of human force and finally the repetition of simple tasks.

The architects entrusted the construction of the King's Chamber and its superstructure to the best teams on site because it was a real architectural challenge that was won with flying colors: 4,500 years later, time has not left its mark on the work.

4 - PROPOSED RECONSTRUCTION OF THE COUNTERWEIGHT SYSTEM: DEVELOPMENTS SINCE THE BEGINNING

For information:
Since 2003 I have received invaluable scientific help from Denis Denoël[64], a retired aerospace architect-engineer, in the elaboration and feasibility of the technical solutions hypotheses imagined for the counterweight system. Everything that follows has been the subject of countless calculations, models and dynamic tests carried out by Denis Denoël[65] .

In parallel to the constant evolution of the method of construction by the interior for the volume, linked to the increase of my knowledge and the clues, to arrive at my current proposals[66], from the beginning of 2001 I had launched into the Engineering of a counterweight moving in the Grand Gallery; for me its use was the only viable solution for the hoisting of the monoliths above the King's Chamber. From the beginning I was aware that the laws of physics would impose numerous constraints to be respected, the two most important ones being: on the one hand, the traction force effectively restored by the

[62] Agriculture in the Nile Valley is at the heart of the development of Ancient Egypt thanks to a very dense irrigation system. The shaduf allowed the transfer of water in the networks.
[63] Which opened the door of Eternity to the deceased.
[64] Member of the ACGP and its Scientific and Technical Committee, Denis Denoël made his career at the S.E.P. (Société Européenne de Propulsion) as a project engineer specialized in motors / rockets.
[65] Some of them were completed by computer simulations performed by Dassault Systèmes with the SIMULIA software.
[66] "Khufu Reborn", abstract: www.youtube.com/watch?v=CwcCTPL-S_0 .

counterweight and, on the other hand, the angle β[67] that the traction ropes could take. In the case of Khufu's Pyramid construction site, there are two applicable traction cases (for one ton and with ropes remaining parallel to the slopes):

Case N°1, the counterweight of one ton moves on a slope of 26,5° (50%) and the load of one ton to be towed moves on an opposite slope of 4,5° to 5,7° (8% to 10%). In this case, the counterweight will be able to pull the load without any additional contribution thanks to the difference between the slopes. This case[68] is favorable to the system.

Case N°2, the counterweight of one ton moves on a slope of 26,5° (50%) and the load of one ton to be towed moves on the opposite also on a 26,5° slope. In this case, the counterweight will not be able to pull the load without additional contribution because of the equivalence of the slopes. The friction of the counterweight and the load on their supports and the friction of the ropes on the transmissions further reduce the efficiency[69] , hence the importance of reducing these to a minimum to lessen the human force that will be required.

On the other hand, as soon as an angle β is created, the pulling force becomes variable; if this angle is large at the start of a pull, the force restored will be greater but will then decrease as the descent proceeds, with the angle β decreasing and the loss will then have to be compensated for. This problem, highlighted in red in the two drawings on page 12, will be reversed for the counterweight rearmament, i.e. when it is reset. It is therefore primordial to keep the ropes parallel to the slope or to minimize this β angle if it is unavoidable.

Based on these unavoidable parameters, I kept trying to optimize the performance of the counterweight I imagined in the Grand Gallery, a structure that, for the architect in me, appeared to be “ghost machinery”, a kind of "slide" that would have had a constructive use linked to the ceilings and the roof above the King's Chamber.

To move forward in my explanatory approach, it seems important to give a quick history about my vision of the counterweight system[70] and the evolutions that followed over time because they lead to the interpretation I propose for the Big Void in the Great Pyramid[71]. The Grand Gallery being one of the main parts of the counterweight system, I designate it under the term GG1 in order to ease understanding all that follows

Since the early days, I have divided the sequences of operations of hoisting the monoliths into two main Phases with possible subdivisions:
- Phase 1 concerns the transfer of the monoliths from the port to a storage area at the +43m level, base of the King's Chamber, i.e. a 83m difference in height. The case N°1 applies here, the counterweight moving in the GG1 and, on the other hand, the load to be hoisted being towed on a ramp of lower slope.

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[67] The angle of a slope to the horizontal is called the angle α. When the pull cords are parallel to this slope, they follow this same angle. As soon as they go beyond it, the new angle to the horizontal created is called angle β.
[68] The monoliths arriving at the port had to be hoisted up to the level of the King's Chamber before its construction could begin.
[69] Eventually, the yield may be reduced by half.
[70] This term encompasses two definitions at once:
- The first one, all the elements entering in the composition of a particular counterweight with on one side the *tractor*, a trolley and its load, and on the other side the *towed* one, a sled or a platform of transport of the monoliths to be hoisted, to which it is necessary to add the ropes and all other devices necessary for the good functioning of the set.
- The second, the set composed of the various counterweights defined above having been implemented for the hoisting of the monoliths from the delivery port to their final place in the pyramid.
[71] In order to better understand the architectural intentions of the designers for the past twelve years, all my CATIA 3D models of Khufu's Pyramid were made in Egyptian measurements (cubits, palms and fingers).

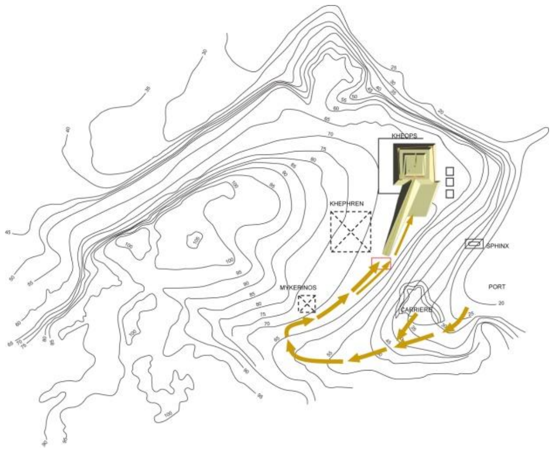
- Phase 2 concerns the setting of the monoliths in the superstructure from the storage area at level +43m up to level +62m, for a difference in height of 19m. Case N°2 then applies, with the counterweight moving in the GG1 and, on the other hand, the load to be hoisted being towed on an opposite ramp-slide of equivalent slope. Phase 2 is, a priori, less favorable to the counterweight.

History of the Counterweight System:

A - First period, from 2001 to 2005.

The delivery of the monoliths from the port to the +43m level was done in two phases:

- Phase 1A, from the port to the base of the external ramp through the wadi south of the Giza Plateau only by human force taking advantage of the topography and the length of the route allowing a very low slope of about 3%.



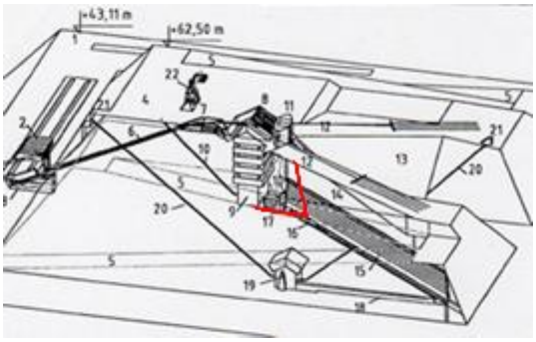
In beige, the route from the port to the base of the external ramp.

- Phase 1B, from the base of the external ramp[72] to the +43m level, thanks to the use of a counterweight moving in the GG1[73]. This was made of a wooden trolley loaded with the three granite blocks (the ones that now obstruct the bottom of the ascending corridor), for a weight of about 17 tons; it moved on the lateral benches of the GG1, animal grease being used to reduce friction. In this phase, the traction ropes remained parallel to the slope. For the rearmament, the "180° return technique[74] " (or "proto-palan") allowed to limit the traction team to a hundred men. With one end anchored at the top of the GG1 (in the "Portcullis Chamber"), the ropes made a U-turn at the front of the counterweight and returned to the team doing the reset.

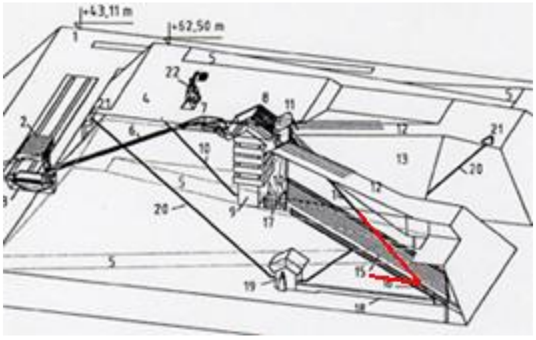
The construction of the King's Chamber and its superstructure was done in one phase:

[72] The ramp arrived against the South face opposite the GG1, following an angle slightly turned to the West to adapt to the topography and start at (elevation 67).
[73] With a slope of 8.5%, the external ramp was 425m long. The counterweight run in the GG1 being 39.60m, it took 11 pull/reset cycles to hoist one monolith. Just to hoist the 43 granite beams and the 22 Turah limestone beams of the roof, a minimum of 715 cycles were needed, not counting the hundred or so granite blocks of the walls hoisted in small groups. We can already see the interest for a system of counterweights in this construction site.
[74] A physical law, which divides by two the theoretical force necessary, excluding friction, but at the cost of doubling the length of the ropes. As the ropes were pulled by men at a fixed post, the length of the ropes was not important. The 180° return technique can also be called the 2 strands technique, one end - or strand - being anchored at a fixed post, the other end being that of the pulled part.

- Phase 2 during which the GG1 remained open and was surmounted by a trench in masonry opening in a void reaching the level of the roof, allowing the ropes to move freely. This 43m high void cut the northern part of the pyramid in two. The performances were penalized by a large β angle. For traction, the weight of the counterweight was increased to 24.5 tons by temporary addition of three 2.5 ton granite blocks. Using the 180° return technique, more than 200 men[75] brought the complementary force to hoist the heaviest beams. Once the monolith was delivered, the overloads were removed by the trench, the counterweight returning to its basic weight of 17 tons for the rearmament. This was carried out by part of the same traction teams[76]; the 180° return technique was used on a second set of ropes connected to the counterweight and dedicated to this operation.



Phase 2, counterweight in high position. The angle β, in red, made by the traction ropes is very important compared to the angle α, that of the slope of the Grand Gallery. (See footnote 67 Page 10).



Phase 2, counterweight in low position. The angle β, in red, made by the traction ropes is not important compared to the angle α, that of the slope of the Grand Gallery. (See footnote 67 Page 10).

In summary, the principle of the counterweight system was plausible but faced several penalizing situations: Phase 1A, from the port to the foot of the external ramp was not in the logic of such a process; in Phase 2 the construction of the pyramid volume was suspended between the central part and the faces[77], the configuration of the northern part above the GG1 was too complex[78], the loss of traction due to the high friction and the angle β of the ropes had to be compensated by a very high number of pullers for the hoisting of the heaviest beams. That said, the counterweight system was already incomparably efficient vis-à-vis the human force alone, the ability to modulate the counterweight load was an asset for the rearmament.

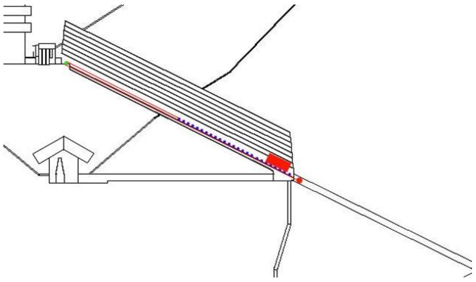
B - Second period, from 2005 to 2010.

In order to improve the efficiency of the counterweight system, several modifications were made during this period, following long studies dedicated to friction supported by experiments on physical models[79], and by discoveries of clues on site:

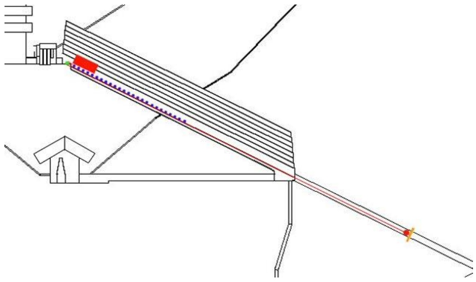
- In 2005, the elimination of friction under the counterweight trolley and under the delivery platform of the monoliths with the introduction of a rolling technique totally within the reach of the Egyptians of the time. The "rollers-train" ensures the spacing and parallelism of the rollers[80] made of Lebanese cedar interposed between the runners of the counterweight trolley and the side benches of the GG1, ditto for the platform for hoisting the monoliths.

[75] Up to 240 men distributed on 2 traction lines of 120 pullers on both sides of the central void.
[76] About a hundred men.
[77] The storage area of the monoliths at the +43m level also had a consequence for the internal ramp of my theory: the 4th section, under the South face, is horizontal, the 3rd section opening under the southwestern edge at the +43m level and the 5th section starting under the southeastern edge at the same +43m level.
[78] The filling of all the voids represented a significant volume of material.
[79] Carried out by Denis Denoël.
[80] The Egyptians used logs to move loaded sleds on prepared roads.

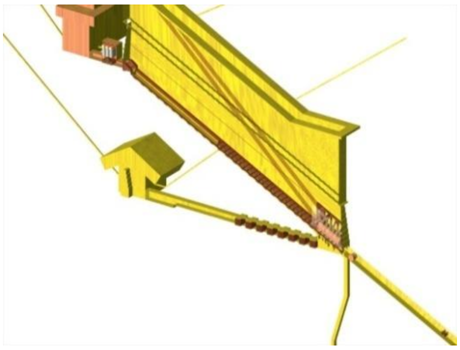
The key to the movement of the counterweight trolley on the GG1 side benches is the use of a rollers-train. During rearmament or restitution, the counterweight trolley moves[81] on this rollers-train, dragging it along. That said, this train moves at half the speed of the trolley and is only about half the length of the GG1. To keep it permanently under tension, the front of the train is connected, by a rope making a U-turn on the platform at the top of the GG1, to a ballast-roller moving in the upper part of the ascending corridor (which I have named "the cat's tail" by analogy).

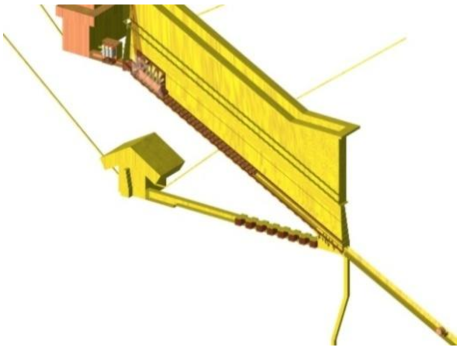


The counterweight, in red, in the lower position, is at the back of the rollers-train, in blue; the tension ballast-roller, in red, is at the top of the ascending corridor.

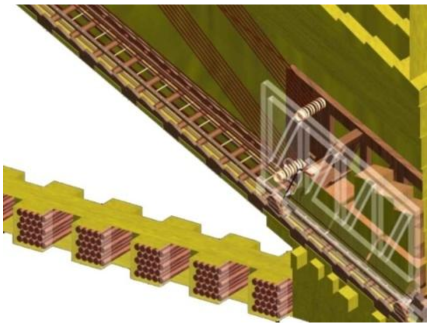


The counterweight, in red, in the upper position, is in front of the rollers-train, in blue; the tension ballast-roller, in red, is in the lower part of the ascending corridor.

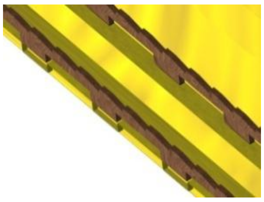


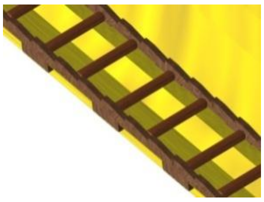


The pull and rearmament ropes pass through the trench in masonry so that they can serve the upper part of the superstructure above the King's Chamber. The angle β varies greatly depending on the position of the counterweight.



The counterweight on its "rollers-train", the spare cedar logs are stored in the horizontal corridor.



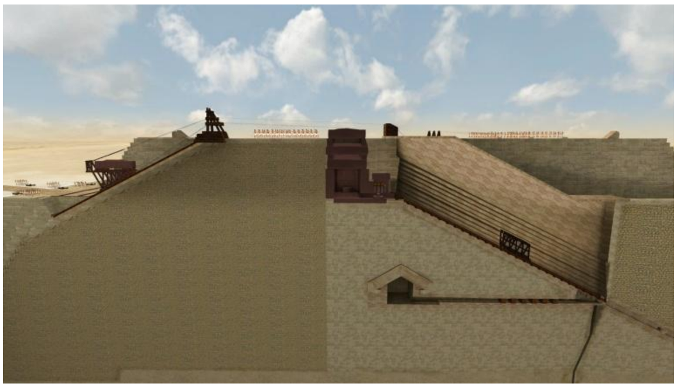


Notched wooden pieces were inserted into the mortises cut into the side benches; they allowed the rollers of the rollers-train to be held laterally and included notches of a ratchet and pawl system for the safety of the counterweight trolley.

[81] Simulations were also performed by Dassault Systèmes www.youtube.com/watch?v=xE39WfQRZL4 .

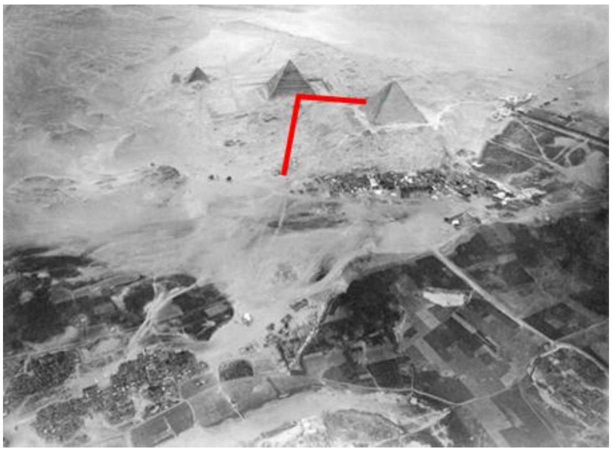
- In 2006, the reset of the counterweight was still carried out using the 180° return technique by a team of about 100 men positioned in front of the GG1 outlet. Before the reset, the counterweight had been relieved of its overloads by the trench, returning to its basic weight of 17 tons. Once reset in high position, the counterweight was again overloaded to 24,5t before a new traction.

- In 2007, seen in cross-section, the counterweight system of the GG1 looked like this during the construction of the King's Chamber and its superstructure.



The delivery platform for the monoliths on the left, the King's Chamber in the center, the counterweight in the GG1 on the right. The latter is surmounted by a trench in masonry leading to an open void. The traction teams operate on either side of the latter. The rearmament is done by another team facing the GG1 outlet.

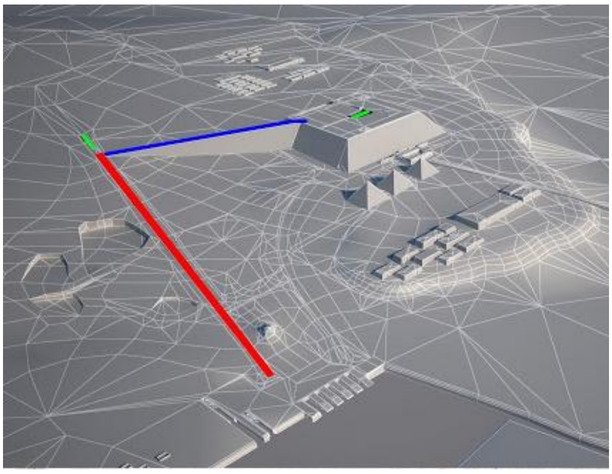
- In 2010, following a remark[82] made by an Internet user on a forum about the transport of the granite beams from the port to the base of the external ramp, i.e. during Phase 1A, the principle of the global counterweight system was greatly reinforced: I understood that the monumental causeway leading to Khafre's Pyramid had been built on an old ramp used for the construction site of Khufu's Pyramid.

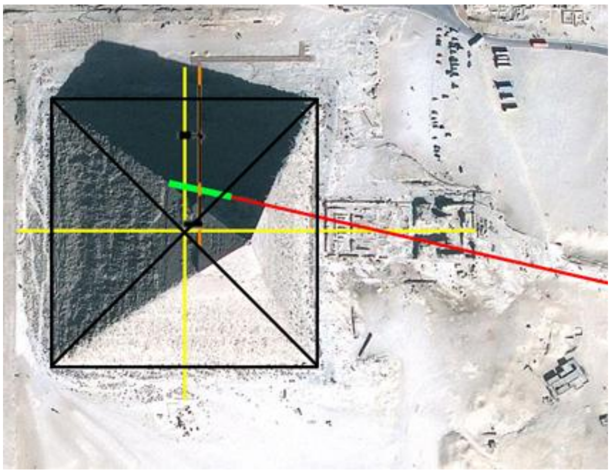


Aerial photo of the Giza Plateau, taken in February 1904 by Eduard Spelterini from an aerostat with my immediate reaction in red: the path of the monoliths during Phases 1A and 1B.

[82] This remark required a clear and realistic explanation. Strangely enough, an aerial photo of the Giza Plateau, taken in February 1904 by Eduard Spelterini from an aerostat, was posted by chance shortly thereafter by Vincent Brown on his blog *Talking Pyramids*. The angle and height of this photo were such that the answer became obvious.

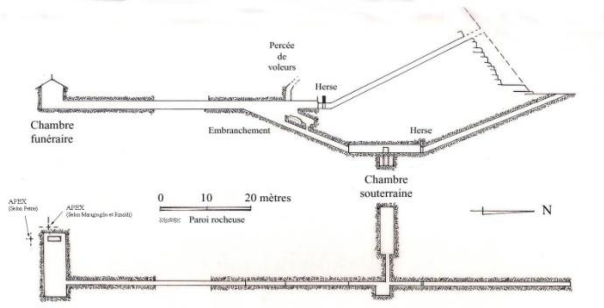
This ramp started from the port and reached the (elevation 73), about 13 meters higher than the base of Khufu's Pyramid (elevation 60). As a result, the external ramp[83] of the pyramid was brought closer to the southwestern edge and rotated slightly towards West in order to have its base connected to the point of arrival of the ramp from the port.
But more than that, this perfectly straight ramp, following the natural slope of the land (8.5% on average[84]), suggested that it could very well have been completed, in the upper part, by a counterweight system running in a trench dug in the bedrock.
The problem: this zone is now under Khafre's Pyramid and thus inaccessible.



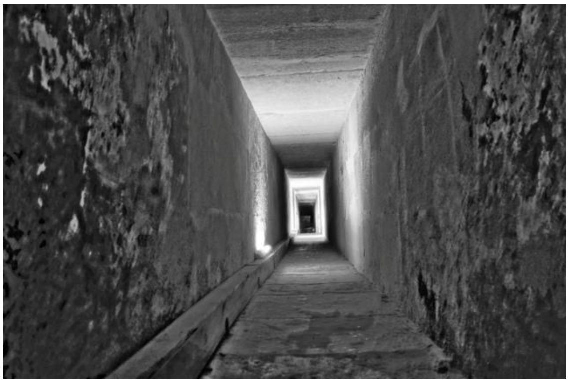


For the hoisting of the beams on the port ramp (in red), the ideal for Phase 1A would be that a counterweight moves at its upper end in a trench (in green).
During the construction of Khafre's Pyramid, this trench could then have created a problem because the access corridor to the Burial Chamber was dug several meters deep, crossing the area in which the trench would have been dug.

The answer: it was in all the known plans of the interior of the Khafre's Pyramid; the horizontal corridor, located at several meters deep in the bedrock, leading to the burial chamber has an anomaly: it is partly built and not dug. More surprisingly, this part built in a trench is exactly in the axis in continuity with the ramp of the port[85] .



Franck Monnier



Mathias Glad

On the left, the interior of the Khafre's Pyramid, the built part of the corridor is represented by 2 thin lines. On the right, the corridor is in masonry, floor, walls and ceiling, on about ten meters of length and dug on both sides.

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83 Khufu's Pyramid being implanted at the (elevation 60), the first 13 meters of this one were built in filling until the level +13m of the pyramid and it remained only a height of 30m to reach. With a slope of 9.4%, it was shorter, 320m long instead of 425m, and less voluminous.
84 When we are on the site, we notice that the hollow areas have been filled in with huge limestone blocks and those in protrusions planed.
85 See document *Critical Analysis of the Giza Plateau*, 1 - History of the Monumental Causeway of Khafre. https://independent.academia.edu/JeanPierreHoudin.

The trench must look like the Great Excavation at Zawyet El-Aryan[86] with the same slope and length of run for the counterweight as for the GG1[87]. The layout of the ramp/slide was the same as that of the GG1, however, the counterweight made of a horizontal platform mounted on skids parallel to the slope also moving on a rollers-train. At each hoisting, the load, calculated[88] according to the weight of the monolith to be towed, was deposited on the platform in the form of granite blocks weighing up to 2.5 tons; once traction was completed, these blocks were removed from the platform for a rearmament without load[89]. The operation was repeated until the monolith reached the top of the ramp.

At the time, the port ramp was approximately 625m long with a slope of 8.5%, requiring sixteen cycles of pull/reset per monolith[90] . Commissioned early in the third year of the reign, as soon as deliveries of Aswan granite and Turah limestone began, the counterweight would have been used in Phase 1A to hoist the beams[91] from the port, as soon as they were unloaded, to a temporary storage area located at the present site of Khafre's Pyramid. As they arrived, the granite and Turah limestone beams were sorted and stored with regards to their final position, by ceiling and by slope of the rafter roof[92], until the beginning of Phase 1B, around the 14th year of the reign[93].

The platform would be dismantled at the end of Phase 1A to be reassembled later in Phase 2 in opposition to the GG1 counterweight.

From left to right: the counterweight trolley in GG1, the counterweight platform in Phase 1A and delivery/counterweight platform in Phase 2, sleds and their load and a granite beam on its sled.

Phase 1B remained identical to the one already described, but with an improvement regarding performances: the external ramp was shorter[94] following its displacement to the West, and the number of pulls required per monolith decreased[95] .

86 See also footnote 85 on Page 15.
87 Case 1, which is favorable to the system, was therefore applied as in Phase 1B.
88 To have a controlled, slow and regular traction, the counterweight was braked by a small team of 4 or 5 men. The interest was to allow the attendants of the pulled sled to slide rollers under the runners of this one with precision.
89 According to the same principle as for the tractions and resets of the counterweight in the GG1 in Phase 2.
90 That is to say a minimum total of 1,040 cycles just to hoist the 43 granite beams and the 22 Turah limestone beams of the roof.
91 The beams were hoisted in segments of the length of the counterweight run, with one segment of rope being removed after each pull.
92 This logistical arrangement will be repeated during the transfer of Phase 1B, with groupings made according to the order of placement of the monoliths.
93 See footnote 59 on Page 8.
94 320m instead of 425m previously.
95 The counterweight run in the GG1 being 39.60m, it took only 8 pull/reset cycles to hoist a monolith, a reduction of about 210 cycles to hoist the 43 granite beams and 22 Turah limestone beams of the roof; and this thanks to a better management of the topography of the Giza Plateau.

Moreover, another major problem was also solved by the commissioning of the port ramp and its counterweight in the early years of the construction: all the "out of gauge" blocks[96] used in the construction of the pyramid between the base of the pyramid and the +43m level were also to be transferred to their final location by this means.

Last but not least, the ramp of the port had a primordial role for the construction of the pyramid: with a 23m[97] width it was a true "boulevard" in the middle of the quarries of local limestone opened on both sides of its course that all blocks of the pyramid[98] took to join the external ramp[99] .

In summary, the principle of the counterweight system earned credibility supported by evidence that is difficult to dispute[100] : the problem of friction under the skids of the counterweight trolley and the monolith hoisting platform was eliminated thanks to the rollers-train, as well as under the sleds with rollers; Phase 1A, from the port to the foot of the external ramp, was now within the logic of such a process, in addition to its extended use to almost all load transports and improving Phase 1B.
The logic of the counterweight system was asserting itself and simplification was underway.

C - Third period, from 2011 to November 2016.

During the presentation of "Khufu Reborn" on January 27, 2011 at the Géode, the counterweight system was now based on two counterweights: the one on the Plateau and the one in the GG1, the monoliths could be transferred without any problem, during Phases 1A and 1B, from the port to the storage area at the +43m level located on the South side of the pyramid. The construction of the King's Chamber and its superstructure could begin.

As in a chain reaction, a very positive logical consequence appeared: the displacement towards the southwestern edge of the external ramp allowed its extension in open trench in the body of the pyramid. This one, rising clockwise to the level +70m[101] in four sections never conflicted neither with the internal ramp[102] nor with the chambers, the corridors and the GG1[103]. This new configuration brought an advantage: the construction of the volume of the pyramid could be carried out during the construction of the King's Chamber and its superstructure, with the exception of the part reserved[104] for the storage of the monoliths on the South face.

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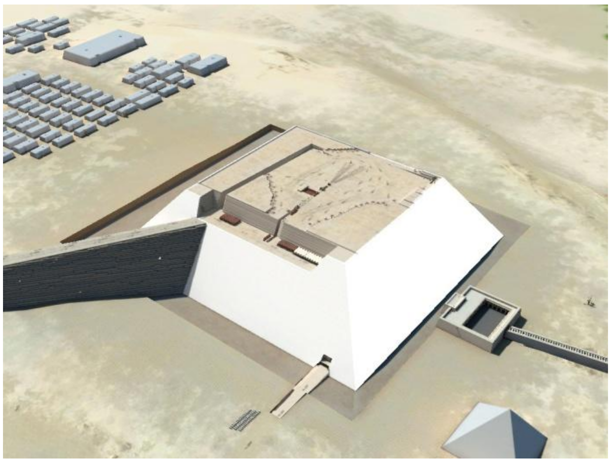
96 All the elements in Turah limestone: huge blocks of the first layer, beams for the rafters roofs of the entrance and the Queen's Chamber, blocks of the GG1.
97 To be compared with the Monumental Causeways of Khufu (10,50m) and Menkaure (8,50m).
98 Except for the standard blocks of the Turah limestone facades which had their own route from the port to the entrance of the internal ramp.
99 And this until the end of its use and its dismantling. The blocks of the upper part of the pyramid were towed through the internal ramp.
100 For the port ramp, later reused for the Monumental Causeway of Khafre: what was the probability to find a proof that a trench existed in its axis at its high end if not that both were realized according to a precise and common plan?
101 At this level, almost 85% of the volume of the pyramid is achieved with the 320m long external ramp alone and its extension in trench, postponing the moment of its dismantling and the use of the internal ramp as the only means of delivery.
102 The internal ramp rising counter-clockwise between the trench ramp and the pyramid faces
103 All these structures are concentrated in a narrow strip along the North-South axis of the pyramid
104 This part created a breach in the South face of about twenty meters high until the end of the construction of the rafter roof above the King's Chamber

Aspect of the pyramid in the 2007 version during the construction of the 3rd ceiling. The construction site of the volume is suspended in periphery at the level +43m.



Aspect of the pyramid in the 2011 version during the construction of the 3rd ceiling. The construction site of the volume continues in parallel, except for the storage area.

As for the GG1, it was now mostly covered, only a vertical well[105] being preserved in its southern part, near the King's Chamber. This well was used for the passage of the ropes of the counterweight which were diverted.

This new configuration had the advantage of completely freeing the space for the traction teams during the hoisting of the beams; the only drawback was that the counterweight load in the GG1 during Phase 2 remained fixed at 24.5 tons[106]. The modulation was done at the level of the number of pullers[107] according to the weight of the monolith to be hoisted. The last logical improvement was that the counterweight was now rearmed by the delivery platform[108], which, once empty, was loaded to about 40 tons[109] at each rearmament cycle[110] .

The delivery platform for the monoliths on the left, the King's Chamber in the center, the counterweight in the GG1 on the right. The latter is covered except for an open well for the passage of ropes in the upper part of the GG1. The traction teams operate at the level of the ceiling to be built above the GG1. The rearmament is carried out using the platform transformed into a temporary counterweight.

[105] The cover of the GG1 has been designed to allow for full opening or spot openings during construction and their closure at the end of the use of the GG1.
[106] The basic load plus the three additional blocks.
[107] About 200 men for the heaviest beams.
[108] The platform thus temporarily regained its original function as a counterweight from Phase 1A.
[109] Loaded with blocks of 2.5 tons easily transportable for about 40 tons.
[110] As the traction force was slightly higher than required, the descent of the temporary counterweight was braked by a team.

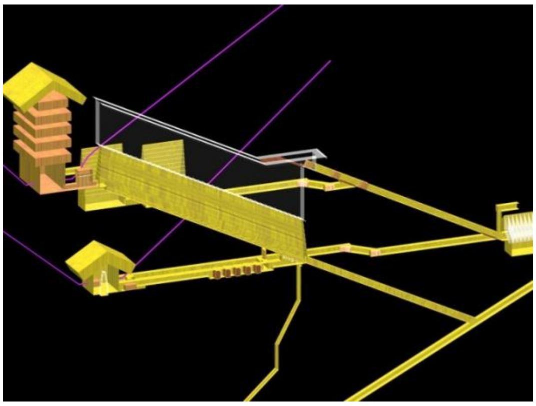
In short, as the construction of the King's Chamber was no longer interfering on the progress of the construction site of the volume of the pyramid, the latter no longer had to be suspended, thus saving precious time[111]; moreover, the reset of the counterweight was done without the use of human force.

However, two very interesting elements appeared:
- The principle of reusing[112] the same equipment, the platform making counterweight of Phase 1A, for the delivery of the beams and the rearmament of the counterweight in the GG1 in Phase 2.
- The notion of a point well instead of a void along the entire length of the GG1.

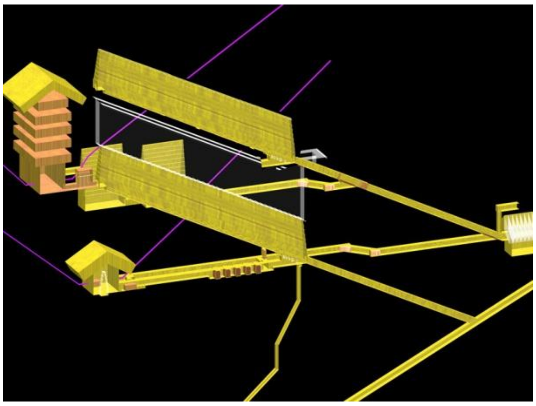
Unfortunately, after all these years of research on the counterweight system, there was still something illogical about the configuration I imagined because:
- Consequent teams of human traction were still needed whereas the available surface diminished as the pyramid was raised.
- The 180° return technique to hoist all the ceilings and roof monoliths could not be used in the GG1 due to the lack of run length for the[113] counterweight beyond the 2nd ceiling.
- The β angle increased as the structure was constructed, with the related problem.
To me, it became clear that the designers had solved these problems I was facing and had gone further in logic and simplicity.

A simple solution floated in my mind: to integrate a second Grand Gallery a dozen meters above the roof of the GG1 and to return to the modulation of the counterweight load in these two ramps/slides. For me, the construction of such a gallery, over several years, was not extravagant at all and all this enterprise and technical prowess[114] had a precise purpose: to protect something north of the King's Chamber[115] .

The next question that came to me was also simple: am I not going too far in my imagination?[116]



Study of a configuration of the GG1 and its trench in masonry (in transparency) in Phase 2 of 2006 with the Noble Circuit and the two antechambers revealed in January 2011 with "Khufu Reborn".



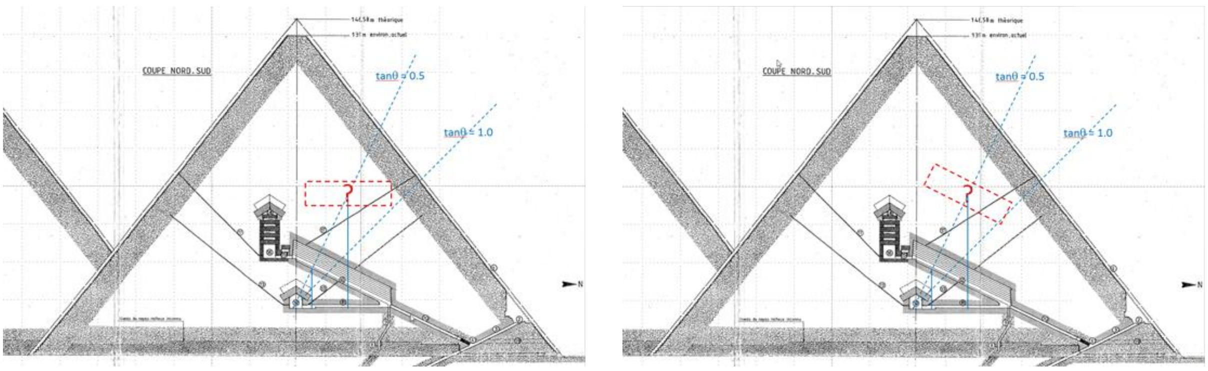
In the early 2010s, the idea of a second Grand Gallery above and in place of the 2006 trench in masonry (in transparency) would not have been extravagant and would have solved the last problems encountered.

[111] The construction of a pyramid was in reality a race against the death of the king whose longevity was unknown. Many kings never had their pyramids ready for their funerals.
[112] When one begins to know the state of mind of the designers of the great Egyptian building sites of the time, one realizes that the notions of reuse or recycling of materials are a constant in the projects.
[113] This is totally illogical when an efficient technique is already implemented in a system, here for the need of human traction.
[114] Two Grand Galleries and an amazing superstructure above the King's Chamber.
[115] See "Khufu Reborn".
[116] Without imagination, Man is treading water. As Albert Einstein said: "The intuitive mind is a sacred gift and the rational mind is a faithful servant. We have created a society that honors the servant and has forgotten the gift".

5 - EVOLUTION OF THE POSITION OF THE ANOMALY DETECTED BY NAGOYA AND KEK BETWEEN NOVEMBER 20, 2016 AND MAY 25, 2017 AND ANOMALIES DETECTED BY CEA[117]

In the first pages[118], I wrote:
.../...
Consequence for me: I was deprived of participating in the mission because of my work Khufu's Pyramid and I will not appear in any document published by ScanPyramids.
.../...
Being part of this project in the background and due to the amount of data that has been accumulated during the course of the project, I have acquired a great deal of knowledge of the file.

Thus, on November 22, 2016 I had the opportunity to attend a working session conducted between the ScanPyramids mission team and the Japanese muography scientific teams from Nagoya and KEK[119] and the French team from CEA. The Japanese announced the discovery of a very important anomaly (Cavity) at the vertical of the Grand Gallery. In the report he submitted, dated November 20, 2016, Dr. Morishima indicated that, for Nagoya, this anomaly would be about 30 m long and that its epicenter was at a height of about 53.30m above the floor of the Queen's Chamber[120]; he also showed the two possible positions for this cavity: either horizontal or inclined parallel to the Grand Gallery below.



Base, Gilles Dormion's plan used by the Nagoya team

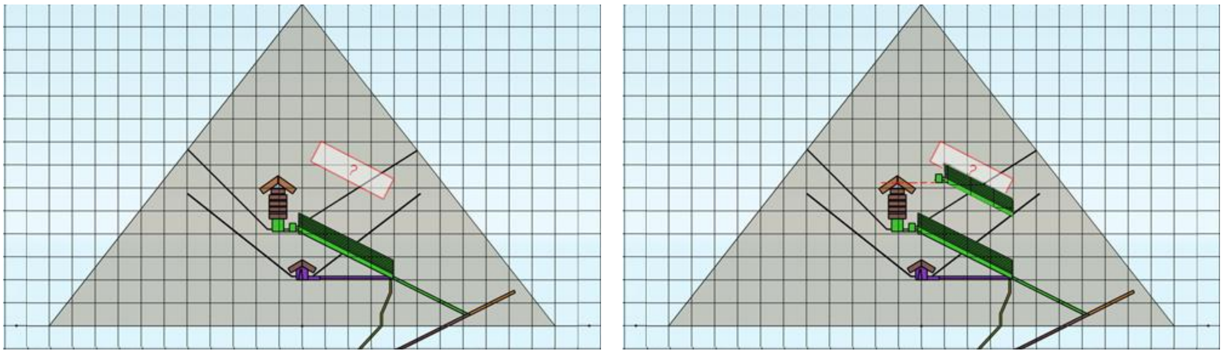
The 2 possible positions of the anomaly detected by the muons of the Nagoya team:
On the left, horizontal, on the right, inclined.

As soon as I saw these images, I told the participants that this anomaly must be linked to the presence of a second Grand Gallery completing the counterweight system[121]. I immediately understood the importance of this discovery because it removed the defects of the system that I mentioned above[122]. It gave back to the system all its logic and a total coherence for the hoisting of the beams and rafters from the port to the roof of the King's Chamber.

After receiving the above sketches on the 25th, the next day I made a first sketch[123] showing this second Grand Gallery that I named the GG2[124] to differentiate it from the known Grand Gallery[125].

117 Led by Sébastien Procureur, the CEA (Commissariat à l'Energie Atomique et aux Energies Alternatives) team had joined the ScanPyramids mission during 2016.
118 See: 2 - GENESIS OF THE SCANPYRAMIDS MISSION, Pages 6 and 7.
119 Both teams had their equipment set up in the Queen's Chamber.
120 That is to say 74,45m from the base of the pyramid (21,15m + 53,30m).
121 Used to hoist the beams and rafters of the structure covering the King's Chamber.
122 See: 4 - PROPOSED RECONSTRUCTION OF THE COUNTER WEIGHT SYSTEM, Page 18.
123 Hastily made on the basis of a CATIA model cross-section made for Khufu Reborn,
124 Referred under the term SPG for ScanPyramids Gallery and later SP-BV for ScanPyramids Big Void.
125 I immediately renamed it the GG1 to differentiate it after this surprising event.

I put the GG2 at a lower level that I considered more realistic, i.e. its high platform[126] at the level +63,05m[127]. Its length was succinctly defined with the principle of traction by 180° in mind[128], estimating its length closer to the forty meters[129] than to the thirty announced.



On the left, position of the anomaly (cavity) tilted version announced on November 20, 2016 by the Japanese; on the right, a few days later, superimposed, the position of the GG2 looking better to me for the counterweight system.

Before this announcement, the length of the GG1 would have allowed to make the first two ceilings using this 180° technique, but not the following ones, so I had to let it go; on the other hand, I knew that it would have had to be nearly 80m long to apply it to all the ceilings and the roof, which would have been unrealistic.

Thinking that the designers had cut in two parts the counterweight system inside the pyramid, at the announced[130] 30 meters, I had to add for the GG2 the length of the counterweight trolley, the margin for the extension of the ropes and the high platform as in the GG1[131].

When designing the project, the architects did not distribute the ceiling levels of the superstructure empirically, but rather according to particular heights that had a technical reason. And they did not order the same type of beams for the three upper ceilings.
When we study these two elements, we see that the "stones still speak"!

In early December 2016, as I re-analyzed the following cross-sectional plan, I suspected that the designers, adept at sequencing, had divided Phase 2 into two separate Phases:

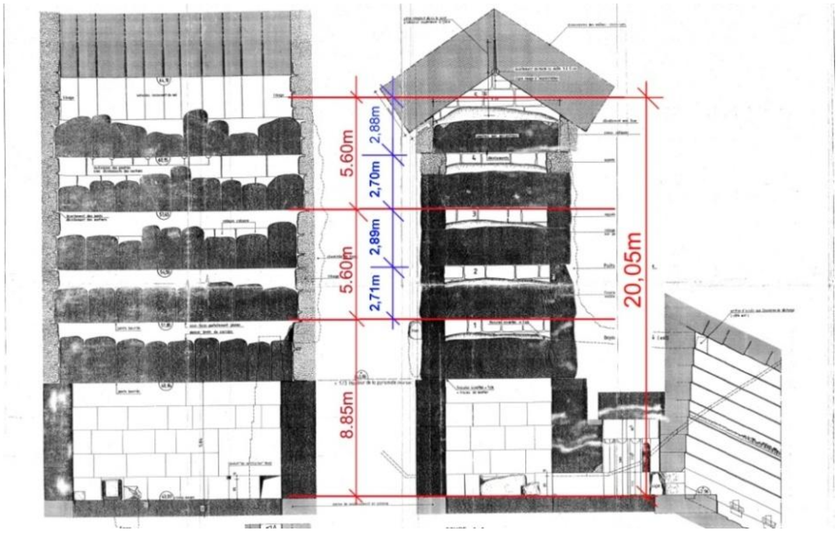
- Phase 2A with the counterweight moving in the GG1:

The 180° return technique was applied and the angle β of the traction ropes was reduced to the strict minimum[132], allowing the construction of ceilings N°1 and N°2 and the hoisting of all the remaining monoliths stored at level +43m onto a new temporary storage area at level +51.85m, that of ceiling N°2.

[126] The upper platform of the GG1 is at the +43m level, base of the King's Chamber.
[127] Before the beginning of the mission, the setting of the rafters for the roof of the King's Chamber was based on a pivot axis at the level +62.10m. Later, taking up my study on the setting of the rafters on the North face, this axis was again slightly raised to +64.10m, slightly lengthening the GG2.
[128] Already described above.
[129] The same length of about 30 meters was applied to the horizontal and inclined anomaly.
Considering that the anomaly was tilted at 26.5°, for me the length of the anomaly announced by Nagoya was that of its projection on a horizontal plane and not its real length along the slope.
[130] This length would have represented only the length of the counterweight run alone.
[131] That is to say in order 5.50m + 1.00m + 1.87 m and a total of approximately 8.40m.
[132] No real influence on the need for traction force.

- Phase 2B with a counterweight[133] moving in the GG2, this Phase 2 being subdivided into two sequences, Phase 2B1 and Phase 2B2:

The 180° return technique had also been applied; the angle α[134] of the GG2 and that of the traction ropes remained parallel[135] . In Phase 2B1, ceilings No. 3 and No. 4 were constructed and all remaining monoliths stored at the +51.85m level were hoisted onto a new temporary storage area at the +57.45m level, that of ceiling No. 4. In Phase 2B2, ceiling No. 5 was built and the roof rafters were hoisted to a final temporary storage area at the +63.05m level. From there, they would be put in place later, once the site installations had been dismantled.



From Gilles Dormion's sectional drawings.

In these cross-sectional plans we can see that the superstructure was carefully designed by the architects to facilitate its construction in successive sequences.

Firstly, at the level of the heights of the beams in granite and Turah limestone:
Those of the 1st and 2nd ceilings are constant and limited, those of the three following ceilings are of very variable heights and those of the rafter roof seem constant[136]. Thus, the height of the beams would correspond to technical parameters related to their final position.

Next, the heights of the hoisting sequences:
In Phase 2A, the counterweight of the GG1 raised all the monoliths above the 1st ceiling to a height of 8.85m. In Phases 2B1 and 2B2, between the 2nd and the 3rd ceiling (2.71m) the height is identical to that between the 4th and the 5th ceiling (2.70m); between the 3rd and the 4th ceiling (2.89m) the height is also identical to that between the 5th ceiling and the axis of rotation imagined for the roof beams (2.88m). Finally, the heights of the sequences of Phases 2B1 and 2B2 are identical (5.60m). Here again, there is no coincidence, but a will of the designers in obvious relation with the run of the counterweights.

[133] This counterweight was in fact the one of the GG1 which had been dismantled at the end of its use; the three granite blocks of the base load had been left in the GG1 while three identical blocks replaced them for the new use of the trolley in the GG2.
[134] The angle α (Alpha) is the angle of the slope of the GG2, which is 26.5°.
[135] The force exerted by the counterweight was therefore constant during the entire traction period
[136] If we refer to the rafters of the entrance on the North face.

Information note N° 1 :

The expression "relieving chambers" should be eliminated when talking about the superstructure above the King's Chamber for the good reason that it does not relieve it of anything! The "ceilings" are not really ceilings either: the first four[137] are struts (or buttress) beams[138] that hold up the side walls of a large void, which is referred to in this day and age as an "armored trench"; the fifth is a truss that prevents the rafter beams of the roof from closing in[139]. This structure serves to raise the roof of the King's Chamber as high as possible so that the oblique loads encased by the roof do not push on an area in which there would be a structure to protect[140].
All this effort because the designers had given themselves a gigantic challenge: to offer their King Khufu a burial chamber with a flat ceiling and something else... A technical feat that had never been attempted before.
It is the explicit proof of a very great knowledge of materials, loads, forces, constraints and behavior of a structure: in our time, it is the work of a 'Bureau d'Études en Ingénierie et Techniques du Bâtiment'.

Empty space called "Nelson's room" between the beams/struts of the 2nd and 3rd "ceilings" which sink about 1m into the North and South side walls.

Google Fair Use
Hydraulic struts between the side walls of an old parking lot during the BruCity construction site in Brussels.

Starting on April 20, 2017, a new three-day working session took place in Paris, which I attended on the last day[141]. At this one, the Nagoya and KEK teams exchanged their results regarding SPG[142], the anomaly detected in 2016, and a consensus was emerging around a large cavity directly above the GG1; its height from the floor of the King's Chamber varied slightly between the teams[143], as did its width. Most important to me was the confirmation that this find was directly over the GG1. Its horizontality or inclination was not determined[144].

[137] The first is of course above all a flat ceiling to cover the King's Chamber.
[138] Hence the choice of granite, the only material capable of spanning a gap of some 5.20 m between the North and South walls of the chamber; granite is also very resistant to compression, so the cracks that appeared during construction did not affect the solidity of the structure. See footnote 54 on Page 8.
[139] In reality, the rafters tended to open a few inches (see link above).
[140] In my opinion, the corbelings of two possible antechambers announced on January 27, 2011 with "Khufu Reborn".
[141] I also presented my initial interpretations about the GG2 at this meeting.
[142] See footnote 124 on page 20.
[143] As an example, between 14m and 24m for the two Nagoya researchers present; between 15m and 20m, 20m and less than 30m for the three KEK researchers present.
[144] The possibility of a horizontal SGP being split into several voids was also raised.

On the following May 1st, Dr. Morishima and his team submitted their progress report accompanied by numerous images of data collected by the emulsion plates and simulations performed in parallel. The conclusions[145] of this report were as follows:

- The cross section of this new big cavity[146] is comparable to that of the Grand Gallery (the GG1) and is directly above it.
- Its length is estimated at about 30m but depends on its inclination.
- The center[147] of the new big cavity is located between +55m and +70m from the base of the pyramid, depending on the method of analysis.
- Further investigation is needed to know the precise location and inclination of the new big cavity.

These provided clarifications consistent with what I had imagined in November 2016:
- The Nagoya team had lowered the estimated height of the anomaly from an epicenter at +74.45m[148] to a height between +55.00m and +70.00m, an area in which I had positioned the GG2.
- The cross section was comparable to that of the GG1.

That said, the main lesson to be learned was the fact that neither Nagoya nor KEK could scientifically announce that the large cavity was either horizontal or inclined, based on the available data without a prior architectural study[149].

For my part, it was obvious that a large horizontal cavity of about thirty meters long, with a section comparable to the GG1 and located at the level of the rafters covering the King's Chamber, made no architectural or functional sense!

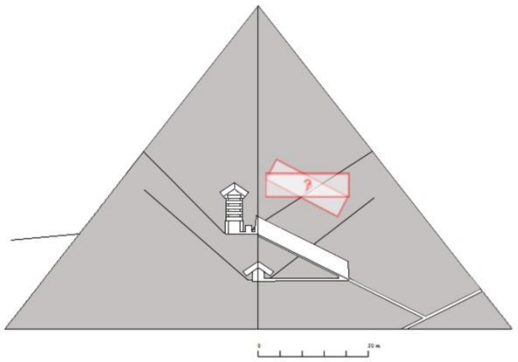
On the other hand, an anomaly inclined at 26.5° reaching the level of these same rafters made sense and could be supported by a precise architectural and functional analysis that could in no way be attributed to chance.

On the following May 17, the Nagoya team produced a new report with numerous simulations of simple models, based on the GG1, positioned according to a dozen possibilities, horizontal or inclined; the architecture was reduced to a minimum and no conclusion was made.

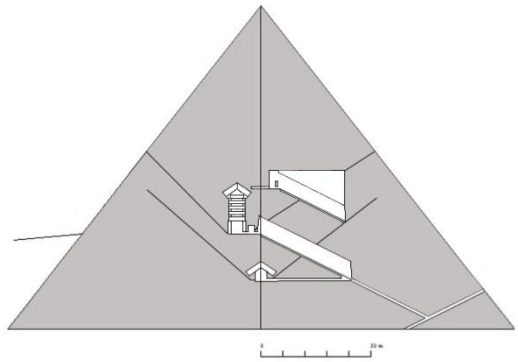
While analyzing these simulations, I went back over the history of my thoughts about the counterweight system and I noticed that I had forgotten an element[150] that had been important but that I had put aside in the last version of January 27, 2011: the possibility of modulating the load of the counterweight according to the beam to be hoisted when I gave up the trench in masonry above the GG1.

I then understood why the scientists could not decide whether the large cavity was horizontal or inclined for a very simple reason: it was the two together. The GG2 had to be completed by a trench in masonry that allowed the modulation of the load of the counterweight, pushing the use of the counterweight to maximum efficiency. The report was accompanied by new information showing three epicenter points A, B and C in a 30m wide zone at 5+Sigma and a point D[151] in a contiguous zone at 4+Sigma, these possibly giving the impression of horizontality. The point D had to be confirmed.

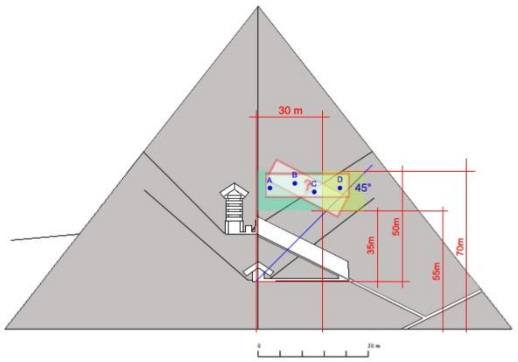
[145] The report also concerned the discovery of an anomaly behind the rafters of the North face entrance.
[146] The term big cavity was now official.
[147] With this precision: the center is not defined as the central position of the cavity because it is calculated by the cross point of the center of the muons excess.
[148] See footnote 120 on page 20.
[149] To define a volume that is compatible with the interior distribution of the Khufu pyramid.
[150] Upon hearing of the anomaly discovery above the GG1, I focused on the 180° return and β-angle technique.
[151] But that was close to the outside of the 45° exposure angle of the Queen's Chamber plates.



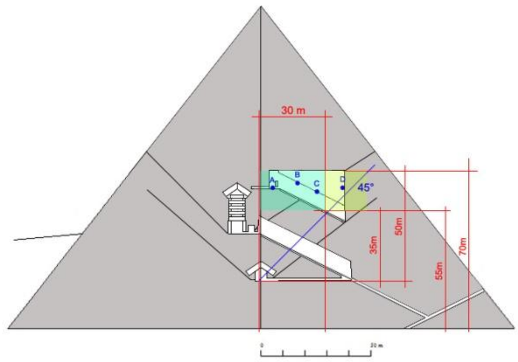
In May 2017 the Nagoya team lowered the potential horizontal or tilted zone in which the anomaly was detected in November 2016 by about ten meters.



As a result, the inclined zone was directly on the GG2 imagined in November 2106; the horizontal zone was superimposed on a potential masonry extension. It allowed the modulation of the counterweight load.



The 4 points A, B, C and D and the announced dimensions of the detected zones above the 45° angle of the muons reception cone: the zones and 3 points are between +55m and +70m from the base of the pyramid on a width of 30m. The points A, B and C were confirmed at 5+Sigma, the point D at 4Sigma could not be confirmed as is.

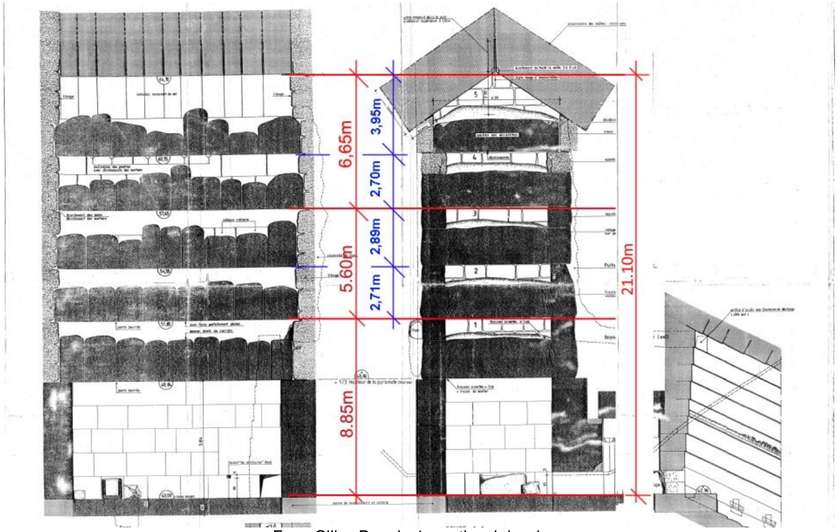


The GG2 and its masonry extension are within the same height and horizontal limits. The blue line of the 45° angle is at the intersection of the red lines +55m and 30m. The top of the extension is aligned with the +70m line. The 4 points are at the epicenter, points B and C on the same slope as the GG2. The future exact position of point D would therefore be decisive.

In summary: since my first sketch on November 26, 2016 the GG2[152] has hardly changed position; however, between November 20, 2016 and May 17, 2017, following the analysis of new data collected over several months, the Nagoya and KEK teams both revised downward the positioning of the anomaly[153] to place it exactly on the GG2 that I refined on May 25, 2017.

At that time I added the trench in masonry above the GG2, with the North wall of the whole remaining in alignment with that of the GG1. As for the GG2 itself, the only slight modification made was related to the technique of setting the rafters of the King's Chamber roof; taking up a study I had made in the summer of 2016 for the rafters above the entrance on the North face, I then set the high platform of the GG2 at the level of the underside of the junction of the roof rafters, i.e. at the level +64.10m[154] instead of the +63.05m previously announced. This modification increased the height to be reached to hoist the rafters in Phase 2B2, this one passing from 5,60m to 6,65m, involving an extension of the length of the counterweight run of approximately 4,70m and the total length of the GG2 to more than 38,00m[155].

[152] As a reminder, the GG2 being my denomination of the SPG as it is related to my interpretation of the anomaly.
[153] About ten meters.
[154] See footnote 127 on Page 21.
[155] Without counting the horizontal technical room in the upper part of the GG2, the kind of Portcullis Chamber of the GG1, which brought the total length to more than forty meters.



From Gilles Dormion's sectional drawings

Phase 2B1 remains the same with 5.60m to climb, while Phase 2B2 increases from 5.60m to 6.65m, resulting in a lengthening of the GG2 by about 4.70m. The total height to be served for the delivery of the monoliths from the base of the King's Chamber increases from 20.05m to 21.10m.

Now, about the anomalies detected by the CEA team:

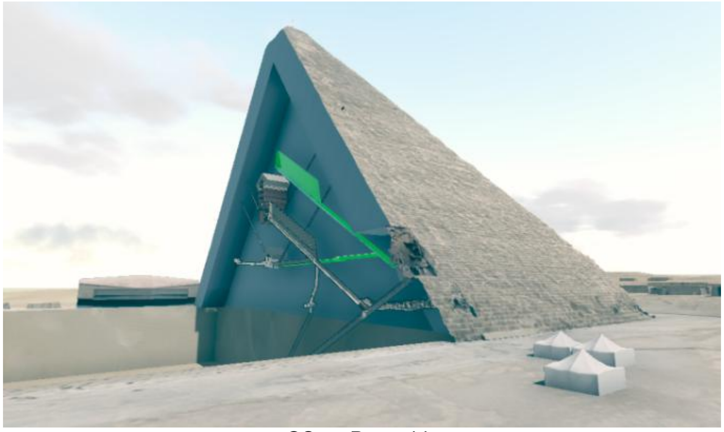
During the working meetings of November 2016, Sébastien Procureur had also reported on the investigations of the CEA in progress[156] with the three telescopes[157] in activity; the first one aiming at the North face at about thirty meters of the northwestern edge and the two others aiming at the South face at about thirty meters of the southwestern edge. These positions had been decided following the discovery[158] in October 2016 of the cavity C1[159] identical to the cavity C2 known on the northeastern edge by these three telescopes.

In the data from the telescope on the North face, two anomalies appeared in an area above the GG1. Sébastien Procureur was asked to make a complementary analysis of the data and if a correlation was established between one of the anomalies and the SPG, to transfer the telescope of the North face just in the axis of the SPG.

Finally, with the correlation made, the three CEA telescopes were transferred[160] in front of the North face in late May 2017 and installed in three air-conditioned tents.

In the previous weeks, a series of models representing several hypotheses have been made by the ScanPyramids team[161], with my participation, to make simulations of cavities that the telescopes could discover.

[156] The CEA's Mission 2.
[157] Named Brahic, Alvarez and Alhazen.
[158] During the CEA mission 1.
[159] See the discovery of C1 and C2 on https://vimeo.com/190875987 .
[160] Called mission 3 by the CEA.
[161] Particularly by Pierre Gable, from Emissive, designer of the 3D models, and Benoît Marini, engineer author of the simulation software for muography.



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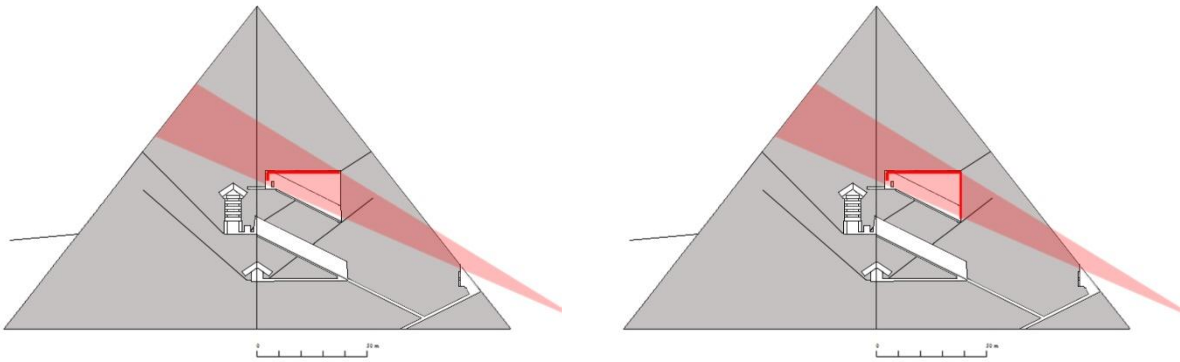
Modeling of a the GG1 type SPG for the CEA in order to simulate the muographic footprint of the three telescopes arranged in tents in front of the North face of the pyramid.

The simulations showed a longer muons reception "picture" in the case of a horizontal cavity compared to a tilted cavity. I had also made some anticipation sketches of what the telescopes could detect, especially about the hypothesis of a the GG2 with the extension[162]



Although I am not a specialist in muography, my understanding of this technique did not pose any problem for the detection of the large cavity from the outside, given its dimensions; on the other hand, in the hypothesis of a GG2 with an extension, thus of a triangular cavity, and of a deviation of a few meters or degrees of the telescopes with respect to the vertical axis, the CEA could interpret the data in favor of a horizontal cavity as indicated by the lines in red.
That said, the important thing was to detect something.

The goal of the mission 3[163] was above all to try to detect the SPG and to have a third muography technique backing the discovery from the outside.

On my side, the beginning of June was very intense, working on a complete update of the counterweight system; unfortunately, on June 11 I was rushed in emergency to the Salpêtrière hospital in Paris in intensive care for a heart attack[164] .

[162] See sketch on page 25.
[163] Mission 2, which was shortened, had however detected the probable existence of other cavities of the C1 and C2 type on the northwestern edge, but, due to a lack of exposure time, the number of Sigmas was not significant enough; the investigations were never resumed.
[164] Fortunately, there were no after-effects other than two stents, an hour of daily walking and lifelong pills.

6 - FROM MAY END TO NOVEMBER 2, 2017, DATE OF THE DISCLOSURE OF THE BIG VOID DISCOVERY IN THE *NATURE* MAGAZINE

Going back to the period between May 30 and June 11, each day[165] brought me ideas for improving the counterweight system; having now endorsed the idea of the masonry extension above the GG2, I was intrigued by the question of points A, B, C and D and the possibility put forward by Dr. Morishima that the SPG[166] could possibly also be made of several successive volumes[167].

From my meetings with Professor Hiroyuki Tanaka[168] , I had kept in mind three important points:

- The first one that the quantity of muons received was dependent on the trajectory, and that the more its angle moved away from the vertical, the more the quantity decreased, to be null at the horizontal; the result is that the muons detectors lose their effectiveness under an angle of 45°[169].

- The second one, that the quantity of muons passing through a mass decreased as they progressed, absorbed by this mass, and that the eventual void(s) passed through slowed down this decrease[170] .

- The third one, that the detectors could not segregate between one or several crossed voids and that the epicenter of a trajectory in a void only indicated an equal length of void on both sides of it but not necessarily in the same void.

In Khufu's Pyramid case and the SPG, because of its shape, the height of mass to be crossed is more important towards the center than towards the faces at mid-distance between the top and the 45° angle; in the first case, there are more muons but a greater absorption because of the height, in the second case, there are less muons but less absorption. Conclusion: between the vertical and 45°, the amount of muons received by the detectors allows a good estimate of the full and empty.

The points A, B, C and D thus indicated peaks of muons reception which could be linked to breaks in the continuity of the masonry riser resulting in an additional uncertainty in the recorded results: the SPG could be at the same time inclined, horizontal and partially made up of separate volumes, a response impossible to imagine without architectural analysis.

In the last version of the GG1 of January 2011, for the passage of the traction ropes, I had introduced the notion of wells at the top of the counterweight slide, a construction technique that was extremely widespread at the time, particularly for the excavation of burial chambers under mastabas[171]. I began to imagine possibilities for wells linked to the four epicenter points, either in a "shield"[172] of the masonry extension or in separate wells. The following two sketches are examples among others.

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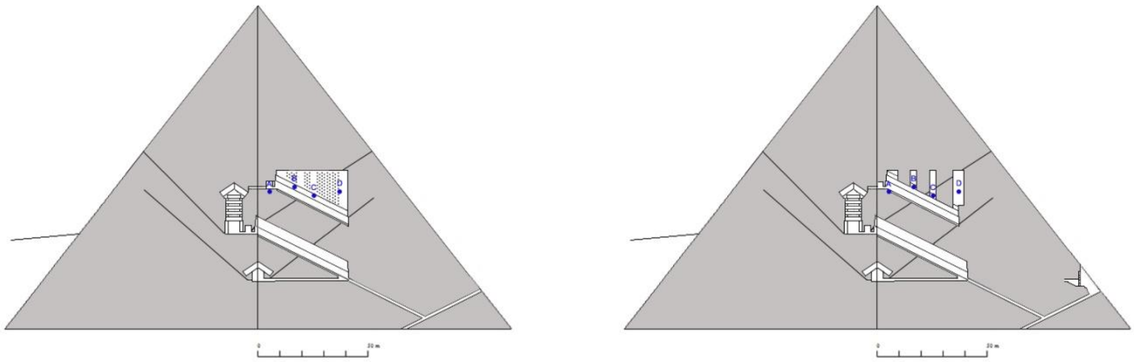
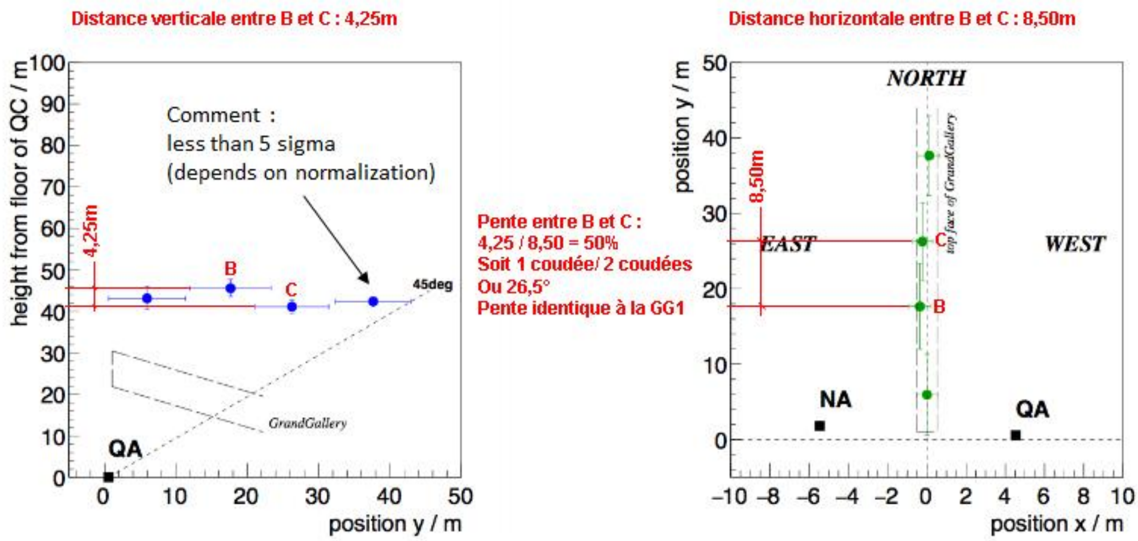
[165] And also almost every night because my brain was boiling.
[166] See footnote 152 on Page 25.
[167] See footnote 144 on Page 23.
[168] See 4th paragraph Page 5.
[169] Hence the importance of the blue line at 45° on the Nagoya diagrams and the D point with only 4 Sigma.
[170] This is why the detectors "see" the voids because they receive more muons.
[171] On the Giza Plateau alone, there are several hundred mastabas built with at least two shafts; the mastabas were themselves built according to a structure of caissons filled with the limestone chips extracted during the excavation of the underground funerary apartments; real giant "molehills", an intelligent management of the excavation waste.
[172] A reinforcement of the masonry extension by pieces of wood between vertical passages absorbing the muons.



On the left a sketch with the masonry extension reinforced with struts leaving vertical passages for the modulation of the counterweight load. On the right a sketch with vertical wells. In both sketches, points A, B, C and D are positioned at the epicenter of the zone between +55m and +70m. At that time, the size and positioning of the vertical voids required more precision in relation to the counterweight runs, but the principle of the wells was endorsed.

In further analyzing the Nagoya report of May 17, 2017, I had also noticed a "discrete" piece of information[173] regarding the relationship between points B and C: the difference in height between these two points from the floor of the Queen's Chamber, where the NA and QA emulsion plates of this campaign were positioned, was 4.25m; the distance in horizontal projection between these same points was 8.50m. These two measurements correspond to the two sides of a right-angled triangle; the slope between these two points is therefore 50% (26.5°), identical[174] to that of the GG1, the hypotenuse being parallel to the slide of the GG2.

For me, this detail spoke volumes about the inclination of the SPG and could become a matter of course if new data were to provide details about the height of point D. If the latter was on the same line of slope as points B and C, there would no longer be any doubt that the anomaly detected included at least one volume with an identical inclination to the GG1.



The position in space between points B and C brings a precise information: they are both on a line with a slope of 26.5° (50%), identical to the slope of the GG1 (on the left, the graph and the graduation of the ordinate are compressed by half compared to the abscissa, confusing its understanding, the GG1 seeming to be inclined at 13° instead of 26.5°).

173 "Analysis of NA and QA 20170517" report (Page 9).

174 To an architect's eye, this was already evident from the graphics published by Nagoya.

The notion of a temporary mastaba construction with wells for the GG2 was becoming retroactively evident for the GG1 as well. This idea of a "central mound[175]" encompassing the GG1 had always been present in the various evolutions of my theory of the counterweight system, but it was now based on a type of structure in the Egyptian architectural landscape of the time, the mastaba.

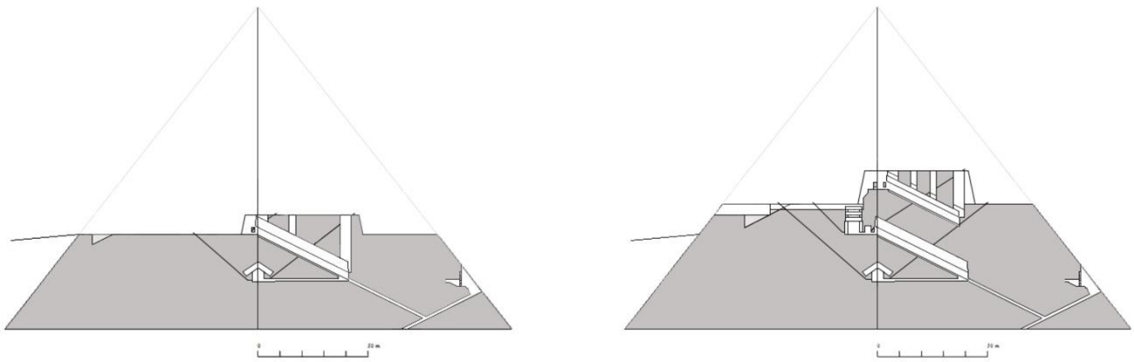
Jon Bodsworth

The mastaba of El-Faraun.

Google Earth

Khufu's Pyramid is surrounded on the East, South and West by numerous mastabas, including those of Hemiunu and Ankh-haf. One can distinguish the wells of construction.

The application of the concept of mastaba and wells was thus at the heart of the construction technique of the King's Chamber, with a first mastaba above the GG1, for Phases 1B and 2A, then a second above the GG2 for Phases 2B1 and 2B2.



On the left, sketch of the GG1 surmounted by its "mastaba" for construction and its wells. On the right, sketch of the GG2 surmounted by its mastaba and its wells. As the ceilings were built, the mastabas were drown in the mass of the pyramid. At the end of the use of the GG1, its wells were filled in to strengthen the structure under the GG2.

This evolution of the counterweight system met the objectives of simplification and logic because it allowed the implementation of the 180° return[176] traction technique for all ceilings and the roof, the modulation of the counterweight load according to the weight of the monolith to be hoisted and the deletion of the use of human force in mass[177].

[175] See sketch Page 12 and 3D rendering Page 18 top left.

[176] The first calculations made by Denis Denoël showed that the efficiency of the counterweight had evolved significantly and that new gains could be made on the side of the friction on the relays.

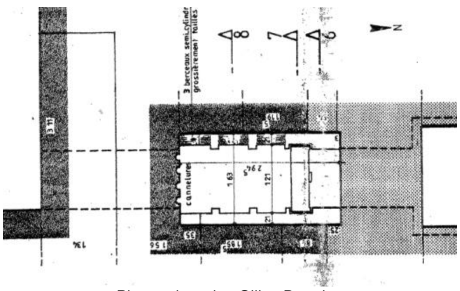
[177] This would have been impossible because of the obvious lack of space available on the construction mastabas. Before this evolution of the counterweight system, additional human force of about 200 men for the heaviest monoliths was needed.

And as with every breakthrough in reverse engineering, solving these problems led me to a new thought in relation to simplicity and logic; an idea sprang up in my mind at the counterweight traction level by rethinking:
- To the interest of slowing down the run of a counterweight to get a smooth and controlled traction.
- To the principle of the elevator, with a passenger cabin on one side and a counterweight on the other; between the two, a small electric motor provides the necessary force to raise the cabin or the counterweight

This is how the idea of the "motor[178] " was born, which appeared to me being the logical continuation of the design of the counterweight system by men of immense creative talent such as Hemiunu and Ankh-haf. The use of a counterweight in the GG2 and the limited space on its mastaba had been the trigger for this idea; while analyzing again the plans of the pyramid, one element jumped out at me: the "so-called" Portcullis Chamber[179]!

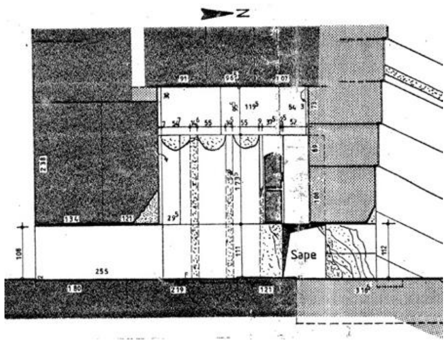
This one is ideally positioned between the King's Chamber and the GG2 to be surmounted by a vertical well having a sufficient height to let circulate the three portcullis, or rather the three "lests[180] " bringing the complement of traction to the counterweight itself; the last element for a perfect modulation of the tractions according to the load to be hoisted. Additional advantage, this complement could be easily braked to obtain a slow and fully controlled traction[181] .

Analyzing the architecture of the Portcullis Chamber carefully, it is obvious that it is not optimized for an efficient blocking function because it had another important role during the construction: to be the base of a well in which the motor of the GG2 counterweight system moved. This room was the temporary shed in which the three motor lests were stored when the counterweight was not in use[182]. The well itself was the exact extension of the North[183], East, South and West walls of the lower part of the chamber and had the same lateral grooves on its East and West walls, ensuring the parallelism of the portcullis-lests during maneuvers.



Plan and section Gilles Dormion

Plan view of the Portcullis Chamber: the section of the well was the same as that of the lower part of the room with the grooves on the East and West walls.



Cross-section: the North and South walls of the well were an extension of those of the room. The portcullis-lests were suspended from logs engaged in the semi-circular grooves of the West wall during periods of inactivity.

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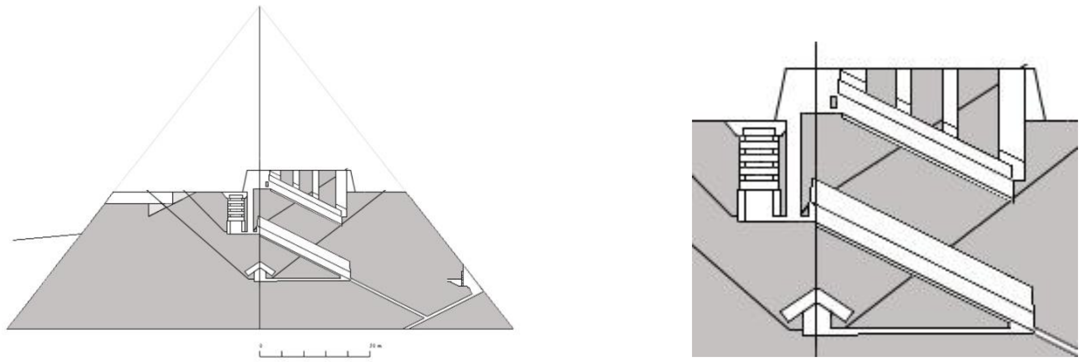
[178] The term "motor" is taken to mean a special device responsible for setting elements in motion.
[179] For me, the name "Portcullis Chamber" reflects only part of its raison d'être.
[180] By studying the parts of the "portcullis" found in the pyramid and the height available between the access corridor to the King's Chamber and the bottom of the semicircular grooves of the lateral grooves, we can estimate the weight of each one at about 2.35 tons (1.18m x 0.52m x 1.43m or 0.87m3 x 2.7).
[181] And recovering a 2.35t portcullis-lest is easier than recovering a 7.05t block in case of an incident.
[182] Compared to the duration of the overall King's Chamber project, the use of the counterweight in GG2 during Phases 2B1 and 2B2 represented only sequences of relatively short duration. The system was therefore out of service between sequences, but its components had to remain ready for use.
[183] The space between the fixed portcullis in the room and the North wall will play an important role during the tractions and the rearmaments of the counterweight.



On the left, a new sketch with the well overhanging the Portcullis chamber. On the right is a close-up view of the shaft in which the three portcullis-lest moved, as part of the motor of the system.

In summary, to hoist a beam of X tons, the counterweight was loaded with Y tons, a load insufficient to pull the beam; the Z-ton motor provided the necessary complement to allow traction. At the top, a small team slowed down the descent of the motor by holding a second set of ropes wrapped around wooden logs, playing with the friction of the ropes[184]. During traction, the safety of the counterweight was ensured by a system of pawls and ratchets displayed along the side benches of the galleries[185] and on the trolley.

Information note N° 2 :

In order to specify the traction forces required to hoist them to their final location, the estimated[186] rounded weight[187] of each Turah granite or limestone beam was again calculated for this study, the breakdown[188] being as follows:

1st ceiling:
9 beams of : 50t / 62t / 56t / 40t / 50t / 49t / 52t / 41t and 38t.
2nd ceiling:
8 beams of : 52t / 45t / 43t / 53t / 46t / 47t / 47t and 50t.
3rd ceiling:
9 beams of: 46t / 47t / 33t / 34t / 39t / 41t / 47t / 48t and 46t.
4th ceiling:
9 beams of : 35t / 35t / 32t / 46t / 39t / 42t / 27t / 29t and 46t.
5th ceiling:
8 beams of: 44t / 33t / 44t / 32t / 41t / 27t / 25t and 46t.
Herringbone roof:
22 rafters (2 pairs of 11 rafters), including 10 of 28t, 6 of 30t, 2 of 34t, 2 of 40t and 2 of 45t.

To summarize the traction forces: from 50t to 62t in 8 cases, 5 at the 1st ceiling and 3 at the 2nd ceiling, all hoisted by the counterweight of the GG1. There are thus 57 beams and rafters of less than 50t on 65 monoliths, the counterweight of the GG2 hoisting only monoliths of less than 50t.
One can understand why this modulation of the counterweight loads was important.

[184] A technique that has been widely used in the navy for centuries.
[185] See details on the four illustrations at the bottom of Page 13.
[186] The irregularity in height of the upper faces of the beams was taken into account at the most unfavorable.
[187] For this study, based on the plans made by Gilles Dormion, the weight of the beams of the first four ceilings was established by considering two cubits in addition to the 10 cubits of span from wall to wall, that is to say a total length of 14 cubits (7.33m for a royal cubit of 0.524m). The beams of the 5th ceiling are 6.20m long. As for the roof rafter beams, their weights are based on the known length of a beam in the roof of the Queen's Chamber and the width of the upper rafters of the North face entrance.
[188] From West to East.

It is also specified that the heights to be reached are based on the levels of the undersides of each ceiling; the runs of the counterweights of the GG1 and the GG2 are calculated on these data. However, due to the way the monoliths were transported, their underside was several dozens of centimeters higher[189], the procedure for their final setting on the supports being adapted accordingly.

As for the beams being much taller than wide, their upper face has grooves to be solidly maintained by the lashing ropes, the beams resting on two cedar wedges inserted between them and the sled.

A typical load, moved on rollers, consisted of the sled and a beam set on two cedar wedges for easy setting.

On the upper face of the beams being much higher than wide, lashing grooves have been dug to ensure stability.

Before delivery, the quarrymen had previously traced the central axis and the lateral marks on each beam for their setting which was carried out from the East side of the King's Chamber.

The ceiling beams of the King's Chamber still bear the traces left by the sap of the cedar wedges on which they were laid on for transport. The first delivered are the most imbued.

The modulation of the counterweight load was achieved by overloading the trolley with granite blocks-lests of the same type as the known portcullis, each lest weighing about 2.25t[190]; not including a

[189] The thickness of a typical load, between the ground and the underside of the beam, was composed of: the rollers under the sled runners, the sled runners and a cedar wedge interposed between the monolith and the sled to allow the transfer of the beam (as in the case of modern pallets).
[190] In order to be laid in the structure of the counterweight trolley, the optimal dimensions of the overload blocks had to be 1.02m x 0.52m x 1.57m (2c x 1c x 3c) for 2.25t (density of granite: 2.7).

special 1.1t[191] one that might be used to fine-tune the traction force to the weight of the beams. The maximum length available for the overload, equivalent to the length of the three granite blocks forming[192] the base load, would have allowed the laying of a maximum of 9 blocks-lests, or about 20t, doubling the weight of the base counterweight, for a total of about 39t.
A series of provisional calculations concerning the traction force needed to hoist the monoliths from 25t to 62t was carried out during this period by Denis Denoël, on the one hand for Phases 1A and 1B, and on the other hand for Phases 2A, 2B1 and 2B2. Without going into details[193], it was already obvious that the principle of the motor moving in the well above the Portcullis Chamber in addition to the counterweight in the GG2 for Phases 2B1 and 2B2 was once again a brilliant idea from the designers, for all the reasons already mentioned above. Thus this idea of a motor must also have been applied in addition to the counterweight in the GG1; it was my project for the following days, but the 11th of June will stop the impulse for a good moment.

That said, within ten days, the definition of the counterweight system had made a giant step forward.

At the beginning of July, I got back in touch with the ScanPyramids teams who were in Paris for a new working meeting of several days in order to prepare a detailed progress report on all the discoveries made by the mission on Khufu's Pyramid since its beginning. This report was intended to be presented to the Egyptian authorities to obtain the authorization to install the equipment in other spaces of the pyramid, the Grand Gallery, the current entrance and the Subterranean Chamber. At the same time, sequences were also shot for a documentary covering the mission and programmed by France Télévision[194] for the fall.

Reading once again my written notes[195] my thinking hours, I saw that as of August 30, 2017 I had written a few lines about an amazing idea regarding the relationship between the well above the Portcullis Chamber and the King's Chamber: the simpler and very likely answer to a riddle[196] I thought I had solved convincingly a decade ago but based on knowledge earned long before the ScanPyramids mission. Again, a consequence of reverse engineering I will discuss in my next document to come.

Finally, a large delegation led by Prof. Hany Helal and Mehdi Tayoubi, including many scientific and technical members[197] of the ScanPyramids mission, went to Cairo to present the results of two years of research[198] to the Egyptian Ministry of Antiquities:
- On September 9, to the Scientific Committee of Egyptologists[199] set up by the Ministry to give an advisory opinion on the results presented,
- On September 13, to the Permanent Committee of the Egyptian Antiquities.

[191] This block had to measure 1,02m x 0,52m x 0,78m for a weight of 1,1t.
[192] These three blocks were identical for the counterweights of the GG1 and the GG2. Those of the GG1 are the ones visible at the bottom of the ascending corridor and were measured; the total length of the blocks is 4.91m.
[193] All the beams, from 25t to 48t, could be hoisted without any problem, without overloading the counterweight for the beams weighing up to 28t, the motor's addition being sufficient. Beyond, by adding blocks-lests on the counterweight, with the maximum of 9 blocks-lests for the 48t beams.
[194] "Khéops, mystérieuses découvertes" directed by Florence Tran (also director of the documentary "Khéops Révélé"), produced by Bonne Pioche for a first broadcast by France 5.
[195] On mail envelopes that I've been recycling as notepads for decades
[196] I mention this detail because it is of great importance to support some of my proposals.
[197] Plus INRIA, represented by Jean-Baptiste Mouret, an organization specialized in robotics that joined the mission with two types of robots being developed for future exploration.
[198] ScanPyramids - 2017 Findings reports - September 9th 2017.
[199] Led by Dr. Zahi Hawass and made up of the following Egyptologists: Dr. Mark Lehner, Prof. Dr. Rainer Stadelmann and Dr. Miroslav Bartá.

Regarding the big cavity[200] discovered by the three muography techniques implemented, the conclusion of this report[201] was as follows:

"The different analyses made by the ScanPyramids team allow us to say that:
- SP-BV is located above the Grand Gallery at a distance from ground level between 50 and 70 meters,
- Its approximate volume is 400m3 (the volume depends on the distance from the ground and the architectural shape of SP-BV which has yet to be defined),
- Its minimum length is 30 meters,
- SP-BV is composed of one or more adjacent structures,
- Its slope is either horizontal or inclined".

Clarification was made regarding the area level in which the anomaly was located: its distance from the ground was lowered by 5 meters, from +55m to +50m and its length was "at least" 30m instead of "around" 30m. That said, the most remarkable indication was about the volume: approximately 400m3.

This discovery was truly exceptional and, scientifically, could in no way be disputed or minimized. Such a volume, equivalent to two-thirds[202] of the Grand Gallery, was something inconceivable before this mission, and should have aroused the enthusiasm of anyone passionate about Ancient Egypt.

However, following the presentation of September 13, the Permanent Committee of Egyptian Antiquities, following the recommendations of the Scientific Committee of Egyptologists, gave instructions to the representatives of the ScanPyramids mission:
- Media disclosure to the general public of the results presented was prohibited at this stage,
- The results had to be published in a scientific framework, i.e. a peer-reviewed scientific publication[203], before being revealed by the media,
- For the next step of the mission, the authorization to install equipment in the Grand Gallery, the current entrance and the Subterranean Chamber was conditioned on compliance[204] with these instructions.

The reaction of the ScanPyramids teams was swift; unimaginable efforts were made by everyone to respect the obligations imposed. All the scientific teams were summoned to Paris at the end of September to write the article to be published. Thanks to the experience of several of the members used to this kind of publication, contacts were made with the scientific reference journal *Nature* and other peer-reviewed journals of the same type.

Judging that the discovery of the SP-BV deserved to be fast-tracked, the journal *Nature* responded very quickly and asked that the article to be published be submitted between October 6 and 9[205] . Finally, this one will be published in *Nature*[206] less than one month[207] later, on November 2nd, to the astonishment of the Scientific Committee of Egyptologists[208] and of the Permanent Committee of the Egyptian Antiquities. The instructions imposed by the latter having been fulfilled, the announcement of the discovery of the "BIG VOID" was taken up by the media[209] worldwide.

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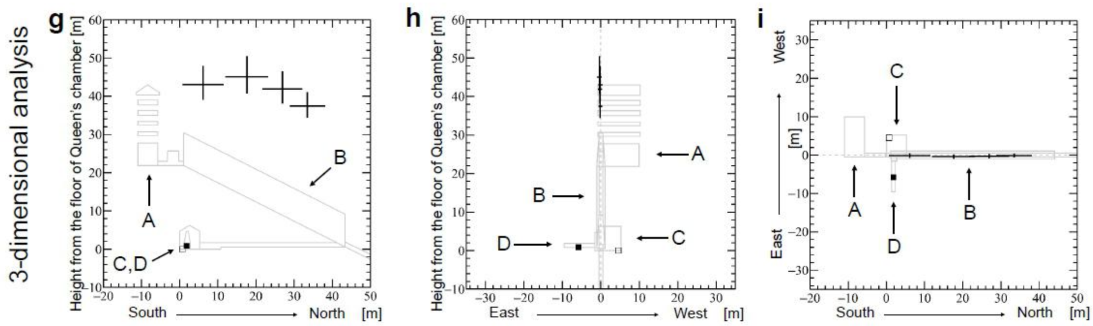
200 Reminder: SP-BV for ScanPyramids-Big Void - see note 124 at the bottom of Page 20.
201 A summary of the report.
202 On the date of the announcement of the results at the Ministry of Egyptian Antiquities.
203 In a scientific article reviewed by experts in the field.
204 When one knows that an article in a peer-reviewed scientific journal can take up to a year to be published, the instructions imposed had the air of a first-class funeral for the mission.
205 This publication will also be shared on the platforms of dialogues between scientists on the same dates.
206 http://www.nature.com/nature/journal/vaap/ncurrent/full/nature24647.html or free version of the same article before peer-review https://hal.inria.fr/hal-01630260v2.
207 That is to say, in an extremely short period of time for this type of publication.
208 Comments that followed, made by some of its members, can be read on the Wikipedia page of ScanPyramids https://fr.wikipedia.org/wiki/Scanpyramids , under "Reactions of Egyptian institutions".
209 I had suggested to Mehdi Tayoubi to take as a comparison the volume of the fuselage of an Airbus A321.

On November 7, the television channel France 5 broadcasted at prime time the documentary "Khéops, mystérieuses découvertes".
To return to the article published by *Nature,* Fig.2 at the top of Page 3 contains three series of information remarkable for their precision; the last series, composed of three diagrams representing the North-South section of the pyramid seen from the East (g), the East-West section seen from the North (h) and the plan view (i) on which the epicenters[210] of the voids detected by muography were plotted as crosses. The position of these epicenters had been specified and, as a novelty, point D had been largely moved following the analysis of additional data.

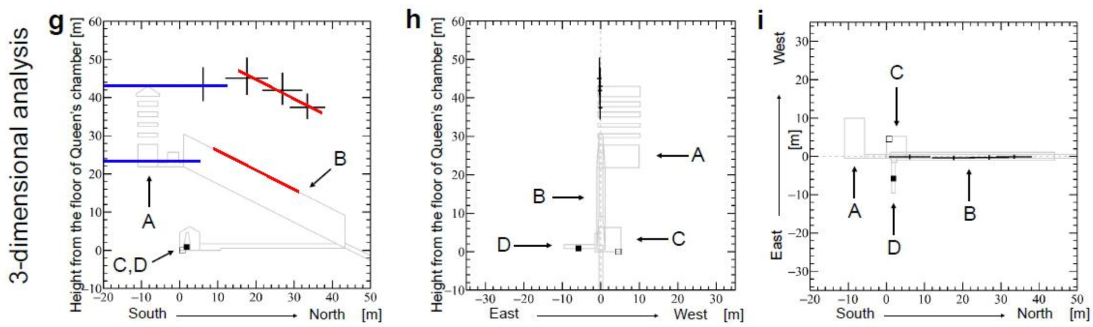
In the last paragraph on page 29, I wrote:

"For me, this detail spoke volumes about the inclination of the SPG and could become a matter of course if new data were to provide details about the height of point D. If the latter was on the same line of slope as points B and C, there would no longer be any doubt that the anomaly detected included at least one volume with an identical inclination to the GG1."

These three diagrams are reproduced below.



Sections (g)[211] and (h) and plan (i). The 4 crosses in section (g) correspond to the 4 blue points A, B, C and D in the sections at the top of Page 25[212] and in the diagram at the bottom left of Page 29.



The additional data clarified the position of the 4th blue dot (D) on May 17, 2017.
This one has been lowered[213] and is now on the same sloping line (red line) at 26.5° as the other 2 blue points (C) and (D), a line which is parallel to the slope of the Grand Gallery (lower red line).

There is now scientific evidence that a large part of the detected void volume, announced as "big void" in the title of the *Nature* article, is on a 26.5° slope. By drawing a line (lower blue line) between the Grand Gallery and the King's Chamber at the epicenter of the Portcullis Chamber[214] , it seems obvious that the last cross representing the blue point (A) of the BIG VOID must be in a volume that is also horizontal.

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210 The epicenters A, B, C and D materialized by blue dots described in the last paragraph Page 24.
211 Also note that cross-section (g) is no longer compressed as it was in the May 17, 2017 report.
212 Not to be confused with the letters A, B, C and D in the above sections which indicate the King's Chamber (A), the Grand Gallery (B) and the emulsion plates installed in the Queen's Chamber (C) and (D).
213 As I sensed when analyzing the Nagoya team's May 7, 2017 report.
214 Between A and B.

More troubling, this point is exactly at the height of the underside of the roof rafter junction at +64.10m (upper blue line), the last height served by the GG2 counterweight.

In fact, since the famous meeting of November 22, 2016 and my phrase "this is a second Grand Gallery", the announcements of results obtained by the ScanPyramids mission[215] has only validated proposals that I had each time anticipated following my analyses.

7 - AFTER NOVEMBER 2, 2017 THROUGH THE END OF 2019

The two instructions imposed by the Permanent Committee of Egyptian Antiquities having been respected to the letter, the ScanPyramids teams were delighted to have overcome a very important stage for the mission and were beginning to prepare for the next step, the transfer of the material to the Grand Gallery, the current entrance and the Subterranean Chamber. The authorization to proceed with these operations seemed to be nothing more than an administrative formality that would not be long in coming. Error...

The Ministry of Egyptian Antiquities has started, curiously[216] , reconsidering the commitments made by the previous Minister[217] and to impose new conditions[218] moving away from Science and Egyptology...

At the top of the second paragraph on Page 7, I wrote:

«Finally, the success of the mission owes much to Professor Hany Helal[219] and Mehdi Tayoubi who had the patience, resilience and tenacity to carry out this extraordinary undertaking.

This sentence can be applied to the entire ScanPyramids mission, and particularly for the period following the publication in *Nature* until early June 2018. At that time, an agreement having been reached, the mission was restarted and the materials transferred as originally planned. The only action allowed during this period had been the change[220] of emulsion plates by the Nagoya team at existing locations.

In the weeks following the publication in *Nature,* I made new updates of my interpretation of the BIG VOID by adapting the GG2 to the latest announced data. Of the sketches made, these below seemed to me to summarize well the general idea that had prevailed at the time in designing the second counterweight system inside the pyramid; the shape and position of the GG2 was beginning to meet both the needs of the construction site and the results of the muography as the comparison of the two shows. I felt that I was getting closer and closer to the optimal shape but still needed more data to get there.

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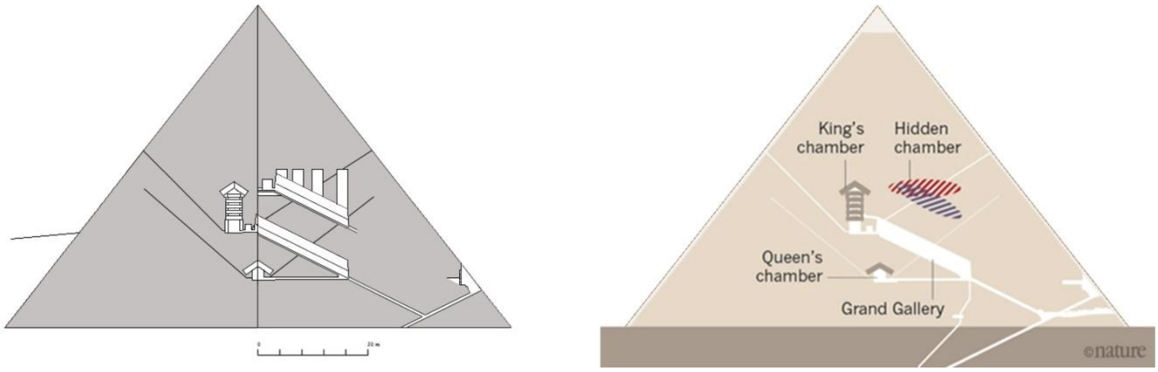
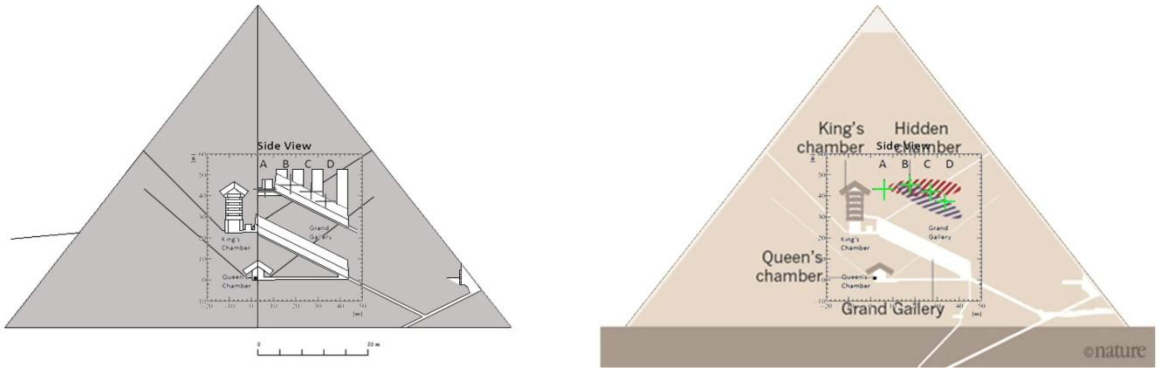
215 The results published in the journal *Nature* by the two other ScanPyramids teams, the Japanese KEK and the French CEA, are accompanied by explicit diagrams on Pages 4 and 5 of the document.
216 Maybe under the influence of someone.
217 Dr. Mamdouh Mohamed Eldamaty.
218 As General Secretary of HIP.Institute, I have been constantly informed about the "negotiations" for several months, so I know what I am talking about.
219 The safeguarding of the mission in this very difficult period is primarily to the credit of Prof. Hany Helal, former Minister of Research and Higher Education from 2006 to 2011, a position that earned him the respect of the Egyptian authorities and all his peers. Hany Helal is a geological engineer, graduate from the Ecole des Mines de Nancy (France), University Rector and former member of the Supreme Council of Antiquities. I also associate Mehdi Tayoubi who did not spare his efforts in these difficult times.
220 Early May 2018.



On the left, the sketch of an evolving version of the GG2, on the right an illustrative cut made for the journal *Nature*.

The GG2 is shown with four wells for modulating the counterweight loads: a lower well for the removal of overloads, two intermediate wells for the loading of overloads for ceilings 3 and 5, then for ceiling 4 and a last one for the roof beams. At the top of the GG2, a shunting room and under it, an access corridor to the GG2 itself (ditto to the GG1 horizontal corridor). The illustration on the right has two oblong areas hatched in blue and red indicating the possible positions of the BIG VOID.



Comparison of the positioning of epicenters A, B, C and D between the sketch on the left and the illustration from *Nature*.

In the sketch on the left, cross A is at the epicenter of a double horizontal volume made of the technical room and the access corridor to the GG2. As in the illustration on the right, cross A is slightly offset from the areas representing the possible positions of the BIG VOID. Still in the sketch on the left, crosses B, C and D are at the epicenter of the voids composed of the three wells and the GG2.

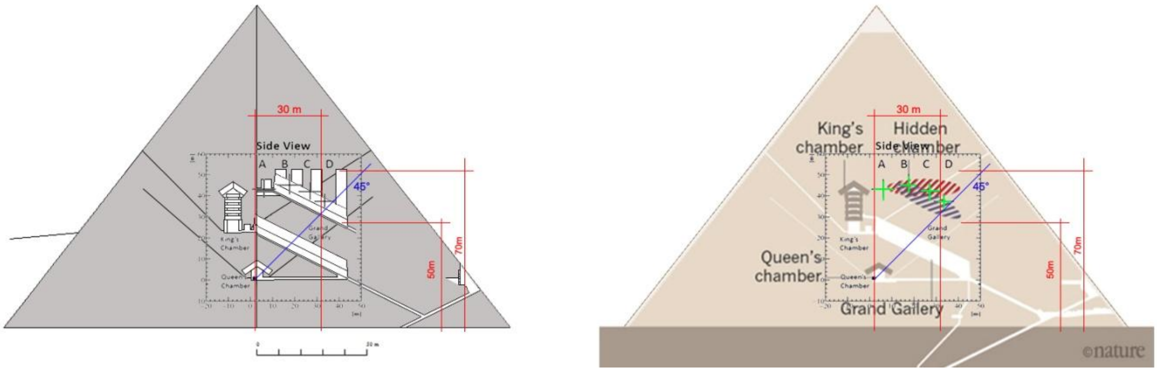
Note: cross D is separated from the lower well by limestone[221].

In the *Nature* illustration, the three crosses (in green for better readability) are at the epicenter of the blue and red hatched areas. This information is important because, on the one hand, if the BIG VOID was a single horizontal volume, the three crosses B, C and D should be horizontal in the red hatched area.

Now, if the BIG VOID was only composed of a slopping volume, these same three crosses should be at the epicenter of the blue area. One can therefore conclude that the BIG VOID is both an inclined volume made of a "single piece" similar to the GG1 and a horizontal volume which would be "fractioned", the three crosses being at the epicenters of the three separate volumes and of the inclined volume

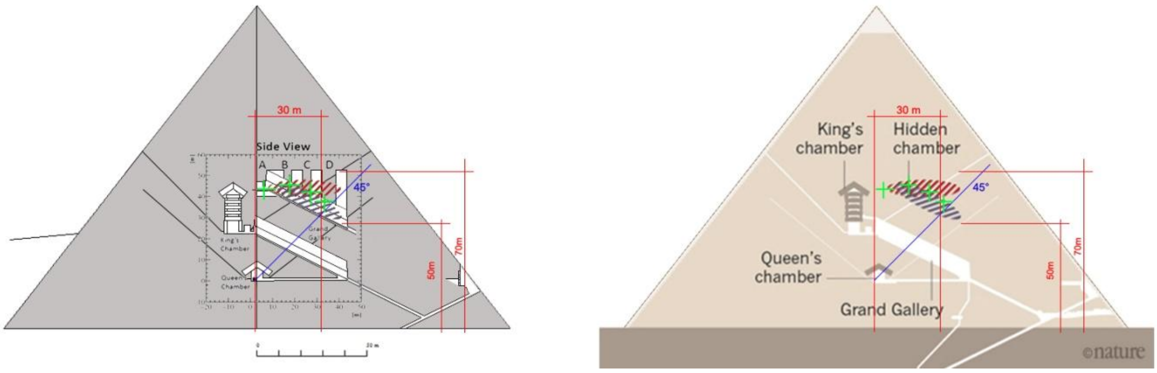
Note: cross D is separated from the red hatched area by limestone.

[221] See 5th paragraph Page 28.



Comparison of the measures announced by ScanPyramids between the sketch on the left and the illustration from *Nature*.

In the left sketch, the vertical line on the right of the 30m width dimension intersects the blue line of the 45° muons reception cone at the underside of the GG2, leaving the part of the GG2 below this line blue outside the detected area, while the bottom of the well is part of it. On the other hand, this same part of the GG2 is between +50m and +70m.
One can conclude that all the voids of the sketch are totally within the announced limits.
Strangely, these same characteristics are found in the illustration made by *Nature*.



To conclude this comparative study, the blue and red areas of the *Nature* illustration are transferred to the sketch on the left.
The layering is perfect.
The installation of muography equipment in the Grand Gallery was essential to obtain more precise data.
The horizontal installation, by Nagoya, of a central box containing emulsion plates at the bottom of the Grand Gallery, was to provide the information that was missing concerning the blue and red zones beyond 30m in width.

After this GG2 update episode, I took a break[222] in my analyses until early summer 2018, with the mission resuming work by the second week of June:

- The KEK team dismantled the scintillator in the Queen's Chamber and rebuilt it in the Subterranean Chamber,
- The Nagoya team equipped the Grand Gallery with four pairs of wooden boxes, distributed along the side benches, each containing several emulsion plates; a last central box was installed in the lower part of the gallery,
- Finally, the CEA team installed two telescopes[223] built especially for this purpose, one in the upper part of the Grand Gallery, the other in the lower part.

These positive events were welcome, both for the morale and for the continuation of the mission. I only had to wait to receive new data recorded by the different materials installed in the Grand Gallery and the Subterranean Chamber.

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[222] The atmosphere related to the situation described in the first part of this chapter did not really invite to a serene reflection about the ScanPyramids discoveries.
[223] Named Charpak and Degennes, they could be installed inside the pyramid unlike the three previous ones which were designed to remain outside.

That said, during my break, on March 6, 2018, I was received by Ms. Aline Gérard, a journalist at the daily newspaper Le Parisien, who was preparing a series of articles concerning the discoveries announced by the ScanPyramids mission in November of the previous year; Ms. Gérard wanted to know my opinion on the BIG VOID. The interview lasted nearly three hours during which I explained at length my work and therefore the reasons that led me to my conclusion. The article[224] was published the following April 29, including a response from me which once again announced in advance a conclusion of the scientists of the ScanPyramids mission which will be made public more than a year later.

Aline Gérard: What do you think is behind this great void?
Jean-Pierre Houdin. The analyses will tell us, but I am almost certain that it is the equivalent of a second Grand Gallery, probably about forty meters long, located just above the other one. I hope it will serve as a breadcrumb trail for other discoveries.

I was already convinced that the BIG VOID was about forty meters long.

Information note N° 3 :

As I said at the very beginning of this document, I have always been in search of information for everything regarding construction at the time of the great pyramids. I have thus been interested in two missions operating in Egypt: from 2013 in the work of the Egyptologist Pierre Tallet[225] on the Red Sea port at Wadi al-Jarf and, from 2017, in that of the Egyptologist Yannis Gourdon in the alabaster quarry of Hatnub south of Deir el-Bercheh. These two missions concern sites that were active during the time of King Khufu, evidence having been discovered on site. Moreover, I also had the pleasure to meet these two Egyptologists to discuss their missions[226] .

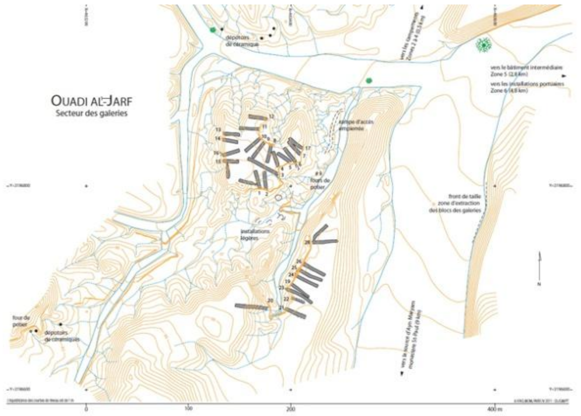
First of all, concerning the work of Pierre Tallet:

The discoveries he made are exceptional because they bring direct and indisputable information in relation to the construction site of Khufu's Pyramid at the level of programming, planning, logistics, stewardship, materials, technical capacities, know-how, supervision and manpower. To quote only some examples of information:
- The organization of a deep-sea port and the facilities necessary for the protection of ships at anchor, their maintenance, the supply of sailors and escorts,
- The seasonality of shipments to the copper and turquoise mines of Sinai, with rotations across the Gulf of Suez between the Wadi al-Jarf harbor and that of Al-Markha.
- Out of season, the storage of dismantled boats in galleries dug in the nearby limestone hills.
- The technique of closing the galleries to protect the boats[227] .
- The optimal use of the topography for the route of the cargo transfer route from the Wadi al-Jarf harbor to the Nile, with the interposition of relay stations and wells for the supply of water to the convoys
- And above all, the discovery of numerous papyri, a real diary of the stewardship of an official, Inspector Merer, some of which describe the delivery of blocks of Tourah limestone to the site[228] of

[224] Egypt: " La pyramide de Kheops cache une chambre secrète " By Aline Gérard. https://www.leparisien.fr/societe/egypte-la-pyramide-de-kheops-cache-une-chambre-secrete-29-04-2018-7689225.php .
[225] And Egyptologist Gregory Marouard, associate researcher at the Oriental Institute, University of Chicago.
[226] Regarding Yannis Gourdon's Hatnub mission, HIP.Institute has participated in the financing, allowing the hiring of more workers to speed up the clearing of the quarry.
[227] A know-how supporting one of the elements of the theory that I will evoke in the future document "Pyramid of Khufu, recent discovery of a cavity under the northeastern edge by the ScanPyramids mission"
[228] Merer clearly indicates that this delivery is destined for the construction site of the pyramid; we can deduce that these blocks were destined for the facades, thus an important piece of information in relation to the construction schedule.

Khufu's Pyramid. The route of the boats is detailed, this one taking two days to go and one day to return.

This information is therefore clear evidence that the great pharaonic sites were above all marked by a total mastery of the entire construction chain[229] *from the beginning of the conception to the final delivery of the monument.*



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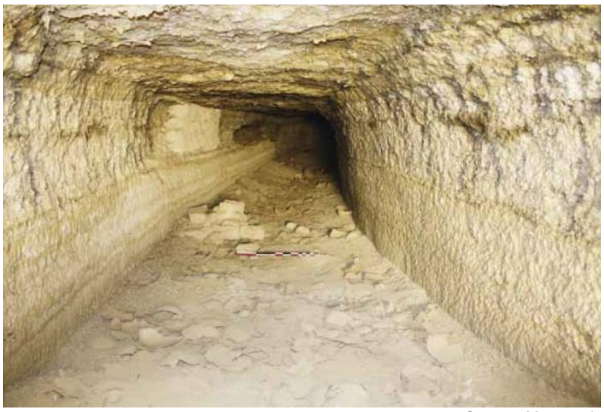
Galleries sector in Wadi al-Jarf
About thirty galleries have been dug.

G. Castel, D. Laisney

Plan of galleries G1a-G1b and G2. Closing blocks are also inserted in the galleries.

Gregory Marouard

Main closing block of the G5 gallery at Wadi al-Jarf flanked by small lateral filling blocks.



Gregory Marouard

Interior of the G23 gallery in Wadi al-Jarf.

Then, regarding the work of Yannis Gourdon:

In the fall of 2018, Yannis Gourdon released a slide show entitled "New research in the alabaster quarries of Hatnub: The Quarry P[230] *". This long document is devoted to three main themes: alabaster and its use in Art and architecture in ancient Egypt, the quarry and its exploitation, from the extraction of the blocks to their transfer to the loading port on the Nile, and finally the inscriptions left by the men working on the site at the time. It is thanks to the latter, found in several places on the walls, that it is established that this quarry was in activity at the time of Khufu. This slide show was then completed by an article published*[231] *in the second quarter of 2019.*

[229] Some information corroborates the points made in: 3 - THE PROBLEM OF THE CONSTRUCTION SITE OF THE KING'S CHAMBER.
[230] Author: Yannis Gourdon, co-director of the Hatnub archaeological mission, French Institute, Cairo, October 7, 2018.
[231] Article: From alabaster quarries to the pyramids: the Hatnub ramp N°93, Page 3 (publication not specified).

In the context of my research, my main interest concerns the ramp for hauling blocks with clues of a traction technique on a steep slope, demonstrating expertise in civil engineering.

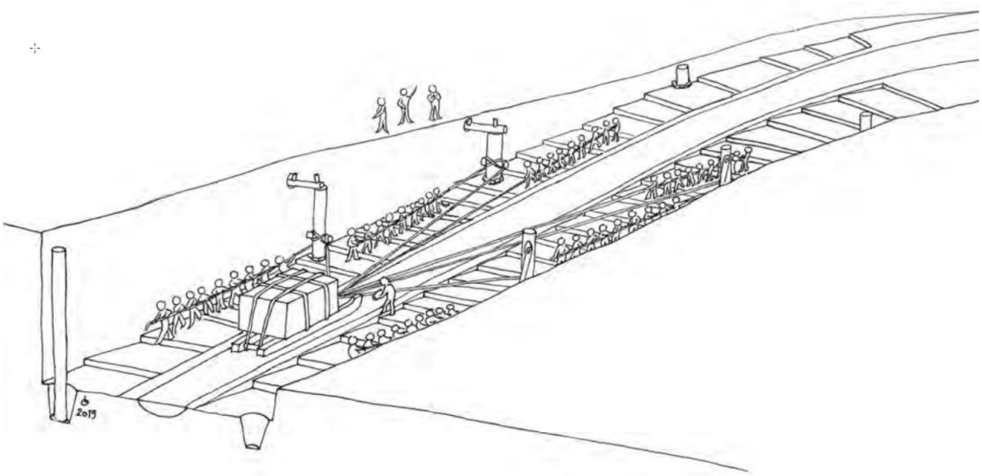
The 2018 campaign completed the clearing, begun in 2012, of the upper part of this ramp that had been filled in over time. The first piece of information shows that this ramp is quite steep, from 20% to nearly 30% in a certain part, well beyond the slopes of ramps usually found during excavations, and that it was used to extract blocks that could weigh more than twenty tons[232]. The second concerns the discovery of holes dug in pairs along this ramp and others on the side walls, sections of stairs on either side of the central passage, and tools, including small stone balls. It is therefore obvious that the Egyptians had developed a system for extracting the blocks based on a technique that reduced traction efforts in order to compensate for certain constraints linked to the characteristics of this ramp: its steepness, its narrowness and its shape, straight at the bottom followed by a pronounced curve at the top.

In the words of Yannis Gourdon "they have led to the discovery of a system of hauling blocks dating from the time of Khufu, a system that would allow us to understand how the Great Pyramid was erected. This sentence[233] , based on an interpretation[234] of the discovery transcribed through two drawings published[235] in accompaniment, are inspired by a technique used by the Greeks for the displacement[236] of blocks intended for the building site of the Parthenon. It reminded me of a technique put forward by the Egyptologist Jean-Philippe Lauer in the documentary " Le Mystère des Pyramides[237] " for the upper part, with more than 30% slope, of a frontal ramp of more than one mile long.

Ifao, Th. Sagory
Aerial view of the ramp that allowed taking out the alabaster blocks extracted from the quarry. Note the curved layout of this ramp.

Ifao, Th. Sagory
Close-up aerial view of the curved part of the ramp. The holes in the left pair are on either side of the ramp, while those on the right are both on the same side of the ramp, centered on the axis of the straight ramp portion. Note the well-marked central area of the ramp at the edge of the lower hole.

[232] Based on the estimated weight of the block of raw alabaster extracted for the realization of the sarcophagus of Hetepheres visible in the museum of Cairo (density of the alabaster: 2,3).
[233] Which could only interest me.
[234] Which is offered in conditional form.
[235] The first drawn by Olivier Lavigne in the 7/10/2018 slideshow and reproduced on the next page, the second in the article (see note 232 above) under © Ifao, Th. Sagory.
[236] The aim of the technique was to slow down the descent of blocks extracted from a quarry by using the friction of the ropes on logs solidly anchored vertically in the ground; a technique totally unsuitable for hauling upwards, even less for hoisting very heavy blocks.
[237] Directed in 1998 by Jean-François Delassus and produced by Point du Jour for France 2. This documentary is at the origin of my adventure at the Pyramids!



Ifao,O. Lavigne
Preliminary synthetic view of the Hatnub hauling system proposed by the author of the documents mentioned.

As much as I agree with the first part of this sentence, "they led to the discovery of a system of hauling blocks dating from the time of Khufu," as much as I cannot understand how the Egyptians could have hoisted these alabaster blocks with the proposed solution[238] . A mystery for me.

Ifao, Th. Sagory
View on the central zone well marked in the high part in curve of the ramp. Note the convexity of this one and the numerous small cavities dug in the ground.

Ifao, Th. Sagory
Grouping of numerous small spherical blocks found on the site during excavations that may have a link with the cavities noticed on the left photo.

This information is therefore also evidence that during the construction of Khufu's Pyramid, the Egyptians had developed a traction technique that allowed them to hoist very heavy loads on a slope of up to 30%[239], even in remote areas. The description of the above findings would be, in my opinion, the clues to the implementation of the 180° traction technique[240], the same as the one used on the site of Khufu's Pyramid in the counterweight system. The only difference is that human force[241] would have been the only one used for the traction, the men being positioned on the plateau at the upper end of the ramp.
But this necessary force would have been, including friction, divided by two with respect to the force required in the above-mentioned version, just by implementing a simple law of physics.

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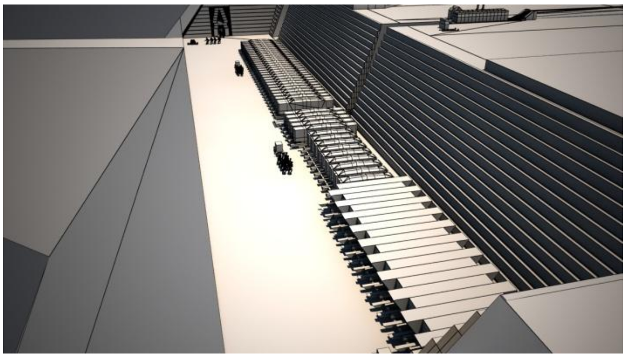
[238] On the other hand, this technique is very appropriate for braking. It is proven that it was known to the Greeks. It should also be remembered that the latter drew much of their know-how from ancient Egypt.
[239] Slope approaching the 50% of the ramp for hoisting the monoliths of the structure above the King's Chamber in Phases 2A, 2B1 and 2B2 of the counterweight system I imagine in this paper.
[240] I will stop here in the description of this technique adapted to the Hatnub ramp which is not the subject of this document.
[241] In the current state of knowledge regarding the ramp. It could be different if future excavations with clearings of this ramp show the existence of a well centered on it, beyond the upper end of the straight part upstream of the curve. A correlation between its depth and the spacing between the pairs of holes along the lower part could mean a lot.

Starting in the summer of 2018, pending further results, I devoted myself to refining the configuration of the GG2 and reconstructing the likely optimal sequences for hoisting the monoliths from the temporary storage area[242] at the foot of the external ramp until the end of the construction of the King's Chamber and its superstructure.

At first glance, this might seem unimportant, but the success of the solution devised by the designers was based on a succession of very precise hoisting sequences for the monoliths, with the position of the beams of each ceiling and the roof at each transfer conditioning their placement when the time came. As an example, Phase 1B, the hoisting of the sixty-five monoliths from the base of the external ramp to the storage area at level +43m on the South face: the sequences distribution of transfer of the monoliths from my 2011 theory version had to be modified with the introduction of the GG2; the old grouping of beams no longer met the constraints of the setting sequences above the King's Chamber and the available space. This shows the degree of organization of the site by the designers, nothing being left to chance.




In the last version, above, of my 2011 theory, the distribution of the beams on the storage area at the +43m level had been established based on a placement order using the GG1 alone.
At that time, the monoliths remained on this area until they were set in place.
Thanks to the GG2, a new methodology will be induced allowing resuming the construction of the South part of the pyramid as the ceilings are being built, simplifying the progress of the site.
The distribution of the beams on the storage area at level +43m is different and meets this new methodology.

In September 2018 and in May 2019, new working meetings gathering the ScanPyramids teams took place in Paris. Each time, the scientists gave an update on the progress of the mission, the time being to collect as much data as possible.

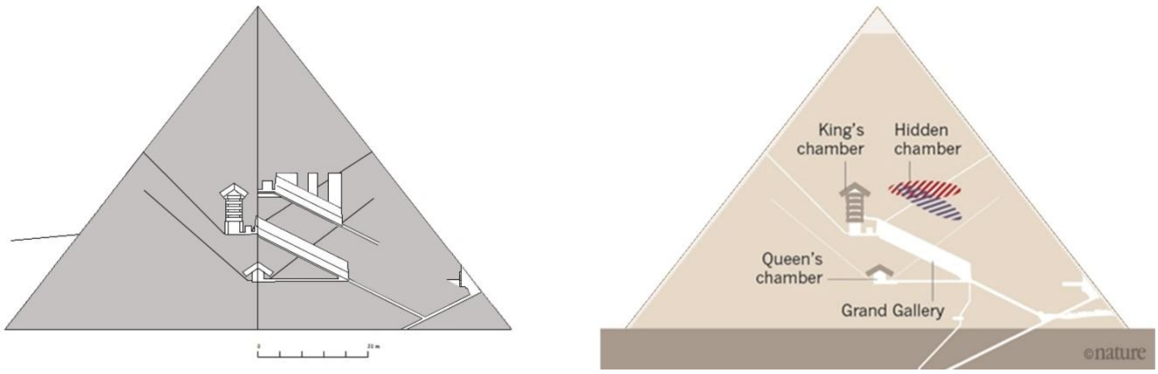
During this period, I had many exchanges with Denis Denoël; the aim was to define an optimal shape for the GG2 according to the traction lengths among several solutions for the hoisting sequences in Phases 2A, 2B1 and 2B2. After analyzing the advantages and disadvantages of each, on January 10, 2019 I sent an email from Los Angeles[243] to share with him the latest draft concerning the GG2 that I had retained; I reproduce an excerpt:

"In the meantime, I'm "clearing my head"...enjoying a bit of "retirement"...but I still "get" things....like for the GG2...3 wells only because the Turah limestone beams and the granite beams of the 4th ceiling share the same well (the highest), as the 3rd and 5th also share the same well (the middle one)
It was the circular hole in the West wall under the rafters on the South side that convinced me...along with the holes dug on either side on top of the 5th ceiling beams...

Simplify the processes...the guys' fundamental principle...3 wells are better than 4..."

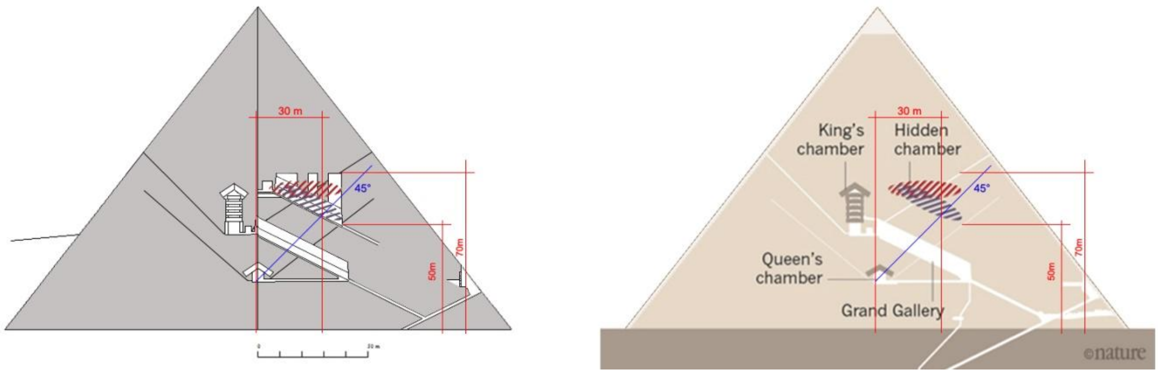
[242] See second paragraph on page 6.
[243] Where I spent a few weeks on vacation.

In this new version, as for the GG1, I added a section of ascending corridor, for the tension ballast-roller, with a minimum length equal to the run of the rollers-train. Its extension seemed to arrive directly in the corridor detected behind the rafters of the entrance. Regarding this one, emulsion plates being installed in the current entrance, future data collected could provide more precision on the exact position of the corridor. That said, all of these volumes discovered in the northern part of the pyramid, on the same axis, clearly showed a global plan linked to design and not the result of a succession of chances. And always more progress in simplicity.



On the left, the sketch of this new version of the GG2, on the right the illustrative section realized by the *Nature* magazine.

The new GG2 is designed with three counterweight load modulation wells: a lower well for the removal of overloads, an intermediate well for the loading of overloads for ceilings 3 and 5, and an upper well for ceiling 4 and the roof beams. This last well is longer to accommodate the two different heights to be reached.
In the lower part of the GG2, a second ascending corridor for the movement of the ballast-roller. A copy of the ascending corridor part at the bottom of the GG1, which I call "the cat's tail[244] ".
To the trained eye, the extension of this corridor appears to lead behind the rafters of the entrance, exactly where the second anomaly named SP-NFC[245] was discovered.
The illustration on the right has two hatched areas in blue and red representing the possible positions of the BIG VOID.



The blue and red areas of *Nature*'s illustration are transferred to the sketch on the left.
The overlay is always perfect.

Following the last meeting in May, the summer that followed was devoted to the preparation of a scientific report summarizing the history of the actions undertaken and the discoveries made.
This progress report was intended for the Ministry of Egyptian Antiquities with the hope of continuing the ongoing investigations and paving the way for a new series of techniques.

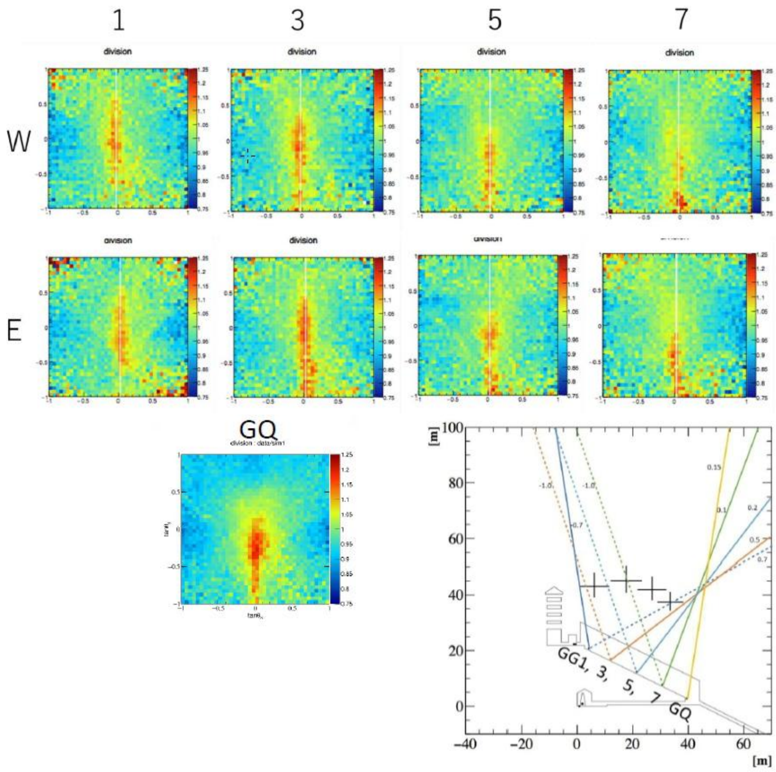
[244] See 1st paragraph Page 13.
[245] SP-NFC for ScanPyramids - North Face Corridor. This discovery will be interpreted later in the paper "Khufu's Pyramid, recent discovery of a corridor under the North Face by the ScanPyramids mission."

Finally, this 68-page document, entitled "2019 Scientific Report - September 2019", compiled by Mehdi Tayoubi and reporting the latest progress of the mission, was handed over to the authorities in early October. The introduction reads:

"Since 2015 ScanPyramids is using three different non-invasive and non-destructive techniques to look through the Pyramids and detect unknown significant voids:
- Infrared technology,
- Muography ,
- 3D reconstruction and simulation,
As of October 2019 :
- Georadar[246]
,- Microgravimetry[247]
,- Electrical resistivity tomography[248] *,*
would be used[249] *in some specific areas to intensify the investigations".*

In the document, the latest results, after more than a year of data accumulation and analysis by the three teams using muography, fully confirmed those already acquired and provided new and undeniable details.

The analysis of the data acquired from the Grand Gallery[250] by the Nagoya team was accompanied by a series of images[251] representing the muons collected by the plates and a diagram with the limits of the BIG VOID.



The positions of the plates are shown in the diagram.
The probable limits of the BIG VOID are within the solid oblique lines of color.

[246] Three university teams from Germany, Italy and France were scheduled.
[247] Project prepared by a team from the University of Rennes.
[248] Project prepared by a second team from the University of Rennes.
[249] Note that in the 2005 mission draft, these three techniques were part of a second group selected to complement the non-destructive techniques selected in the event of their success.
[250] All along the Grand Gallery, on the side benches on either side and down in the center for GQ.
[251] One for each grouping position of emulsion plates laid in the Grand Gallery.

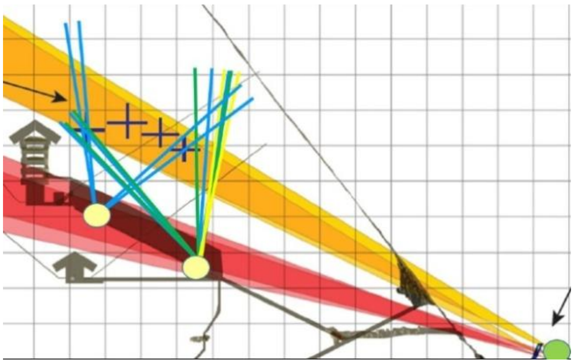
It stated that

"All the data extracted and analyzed in 2019 from position 1, 2, 3, 5 and GQ in the Grand Gallery have confirmed at a confidence level higher than 5 Sigma 2017 SP-BV discovery. The new analyses are consistent with Nature's paper conclusions (position, length, …). The ScanPyramids Big Void appears in the upper images (data/ simulation division) as a central significant red line.
Thanks to those new positions from where SP-BV has been seen the triangulation has been refined. We can now conclude that SP-BV is 40 meters long minimum. No conclusion about the inclination of SP-BV can be drawn from the Grand Gallery data analysis. SP-BV is most likely a continuous void".

The analysis of data from complementary plates positioned in the structure[252] above the King's Chamber showed that the SP-BV was also detected by muography. However, no cavity was detected[253] vertically to the King's Chamber, between it and the summit.
Moreover, the analysis of the telescopes data[254] carried out by the CEA team confirmed point by point the results of the Nagoya team:

"We can now conclude that SP-BV which was evaluated at 30 meters long minimum is, in fact, 40 meters long minimum. This evaluation is compatible with Nagoya University 2018-2019 Grand Gallery measurements".

A diagram was attached.



The green circle on the right represents the position of the telescopes outside in 2017.
The yellow circles on the left represent the telescopes in the Grand Gallery in 2018/2019.
The oblique lines indicate the muons receiving cones. The limits of the SP-BV are inside these lines.

I noted with great satisfaction these two sentences:

Nagoya: "*We can now conclude that SP-BV is 40 meters long minimum."*

The CEA: *"SP-BV which was evaluated at 30 meters long minimum is, in fact, 40 meters long minimum."*

Once again, these results confirmed a prediction I had made nearly two years[255] earlier, a prediction based on accurate studies and not on a whim.
In the conclusions ScanPyramids always came up against the same questions:

"- SP-BV's slope is still difficult to determine but the data acquired from the relieving chambers above the King's Chamber should help. The slope determination depends also on the architectural shapes hypothesis of SP-BV.",

[252] By three plates in Position 2F, i.e. in the second void.
[253] By a plate in Position 5F, i.e. in the last void under the rafters.
[254] Positioned at the top and bottom of the Grand Gallery.
[255] See top of Page 40 about the article in Le Parisien.

"- SP-BV architectural shape is still undetermined".

Finally, the report announced the following steps in "Plan 2020:

For the ScanPyramids Big Void (SP-BV):

- Continuation of muons measurements by emulsion films and telescopes for at least 8 months in the following places: Grand Gallery, Queen's chamber, Descending corridor, King's chamber niche[256] *and upper chambers.*
- Test the efficiency of Georadar, Microgravimetry and Electrical Resistance Tomography in the context of the pyramid for known structures from the Grand Gallery.
- After validation, conduct Georadar, microgravimetry and Electrical Resistance tomography measurements in certain places at the Grand Gallery at certain levels.

The roadmap was drawn for the year 2020...

The year 2019 ended with a new article written by journalist Aline Gérard for the daily newspaper Le Parisien[257]. Two questions asked to Mehdi Tayoubi were interesting because they suggested a possible relationship between the BIG VOID, possibly a Grand Gallery, which now measured at least 40 meters in length, and the corridor[258] detected behind the rafters on the North face:

"Could it be another Great Gallery in a smaller format?
"Could the large void be connected to a secret circuit of corridors?"

And the computer graphic illustrating the article depicted a blow-up of the pyramid with a second Grand Gallery parallel to the known one and at a distance of between 10 and 15 meters above it; the corridor behind the rafters was also depicted.

This brought back memories of another interview[259] that seemed to have had some impact.

On December 18, I left for several weeks in Los Angeles, confident in the future.

And on January 29, 2020, arriving at the Los Angeles airport[260] to fly back to Paris, I was surprised to see hundreds of passengers arriving from Asia all wearing masks on their faces; the first clue that something unusual was happening on the other side of the Pacific.

8 - THE SUSPENDED TIME AND THE TIME TO COME OUT OF THE SHADOW

At the beginning of February 2020, Hany Helal sent an e-mail to the members of the ScanPyramids teams to set a date for a working meeting in Paris towards the end of March; finally, the dates chosen were March 26 and 27. New data were expected from the equipment installed in the Grand Gallery, the voids above the King's Chamber and the Subterranean Chamber.

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[256] In fact the void dug in the shaft passing behind the West wall of the Portcullis Chamber.
[257] An interview with Mehdi Tayoubi published on Saturday, November 23, 2019.
[258] SP-NFC - ScanPyramids - North Face Corridor.
[259] See the beginning of Page 40.
[260] Los Angeles International Airport is the most important point of entry into the United States for travelers from Asia.

But in a few weeks, the health situation related to the newly declared COVID-19 pandemic deteriorated dramatically, leading to the first general lockdown in France on March 16; time had just been suspended for a few weeks that would later become two months. For all French people, life changed radically from one day to the next. For the ScanPyramids mission, it was the entry into uncertainty, the first victim being the cancellation of the working meeting at the end of March. At that time, no one could imagine what was going to happen in the future, no one could make any plans because of this pandemic that had become worldwide.

For me too, time had just been suspended, Khufu’s pyramid passing in the background of my concerns. Trying to get through this "surreal" period we had all just entered without being infected had become everyone's primary concern.

And the suspended time was slowly but surely prolonged, the successive "waves" of aggression of a virus in perpetual mutation being endless. I also began to think that for the ScanPyramids mission an era was over and that its future was no longer guarantee, so much so was it linked to the end of the pandemic. Maybe a premonition...

Until the end of the summer of 2021 I wrote down from time to time ideas that crossed my mind regarding the GG2, how it worked and the details that could still be improved; an intellectual watch that was still productive, accompanied by some quick sketches here and there.

Among these thoughts, there was one point that always deserved some attention: trying to reduce friction at the various rope relays. In the calculations of the hoisting sequences, the materials used, ropes running on rotating logs[261] in greased cylindrical wooden grooves, and the number of returns[262] penalized the efficiency. Researching on this, I realized that friction between contacting materials came from asperities in those materials. Wood on wood and rope on wood was not really the best assembly. On the other hand, high density materials, which have virtually no asperities, have much lower coefficients of friction[263] .

An object that I had come across years ago in my readings came back to my mind. It had been discovered in 1932/1933 by Egyptologist Dr Selim Hassan during excavations[264] on the site of Khentkawes 1’s pyramid on the Giza Plateau, thus a few hundred meters from Khufu’s Pyramid. This object is carved in red basalt from Aswan[265], in the shape of a mushroom, with three grooves and a fixing hole; it is considered by Egyptologists to be a "proto-pulley" that was used during the construction sites of the Pharaonic period.

Dr. Selim Hassan writes in a report[266] of excavations:
« Strictly speaking, one of these pulleys was employed and performed a function in an admirable and excellent manner. In other words, it can be said, high and mighty; the ancient pulley served a purpose as perfectly as a modern pulley can do nowadays”.

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[261] The experiments made by Denis Denoël showed that from 35° of winding of a rope on a log, the latter started to rotate.
[262] Not to mention the more important friction at start-up.
[263] For example, a rope running on polished cast iron has a running friction coefficient of 0.075. For the same rope running on an cedar log, this coefficient is 0.52, or 7 times more.
[264] In 1935, Selim Hassan found a second identical object during excavations near Khafre’s pyramid.
[265] This material has a density of 3.14, almost 20% higher than granite; it is free of asperities like polished iron.
[266] Excavations at Giza, Season 1938/39 - Vol X: The Great Pyramid of Khufu and its mortuary chapel.

Selim Hassan
Side view of the proto-pulley
It is made of red basalt from Aswan, a material chosen for its density and its absence of asperities, thus ideal for a proto-pulley. Note the hole for fixing to a support.

Selim Hassan
Front view of the proto-pulley.
The TWO "ridges" kept in the semicircular part were, in my opinion, to keep the rope lifted from the basalt to minimize the friction at the start.

The problem of friction was therefore known and dealt with by the designers, the choice of a material extracted more than 800 km from the construction site[267] being proof of this. That being, the proto-pulleys used in the counterweight system had to be sized according to their role, those linked to the 180° returns technique of the main ropes being the most important. Their lubrication could also improve the sliding of the ropes, especially since they were never pulled by human hands; one of the great advances linked to the presence of the GG2 in the global counterweight system.

An informal meeting with the people in charge of the mission was planned for August 31, but it did not take place in the end, as everyone's schedules did not allow it. That said, after a year and a half of health crisis, I told myself that I had to take back control of my destiny and that it was high time for me to come out of the shadows: two months earlier I had become a septuagenarian, far from the forty-eight years I was when I started my adventure at the pyramids!
I considered that I had reached such a level of knowledge about Khufu's Pyramid and the ScanPyramids mission that it would be a shame to let them get lost.

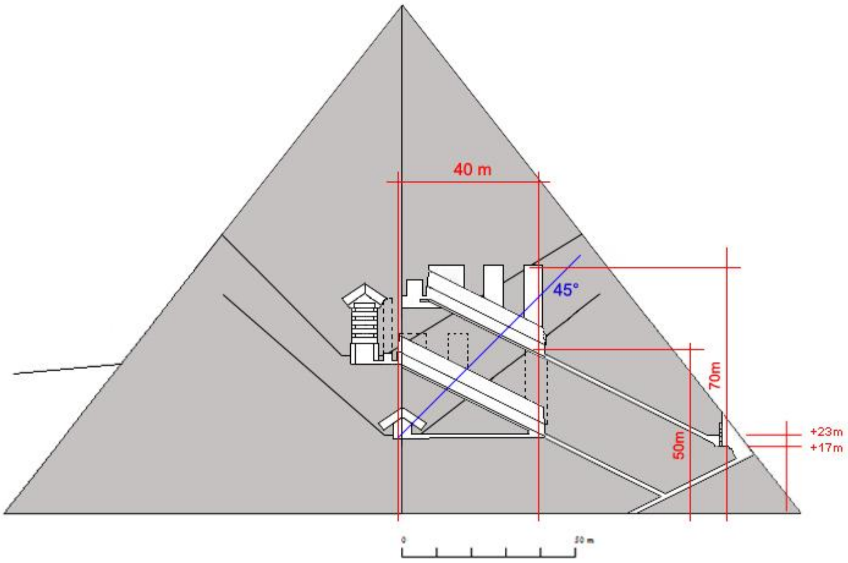
I decided to start writing my interpretations of the three major discoveries of ScanPyramids, starting with the BIG VOID, as this was the key to the reconstruction of the most technically impressive part of the pyramid, the King's Chamber and its superstructure.

I picked up my work where I had left off, that is, after the delivery of the "2019 Scientific Report - September 2019" document to the Egyptian authorities. I was now ready to develop the comparison of the results announced by the scientists to my last updates regarding the GG2 that I had imagined during the months that had just passed. It was time to give a clear and precise answer to the scientists regarding these two famous sentences:

- The slope determination depends also on the architectural shapes hypothesis of SP-BV,
- SP-BV architectural shape is still undetermined.

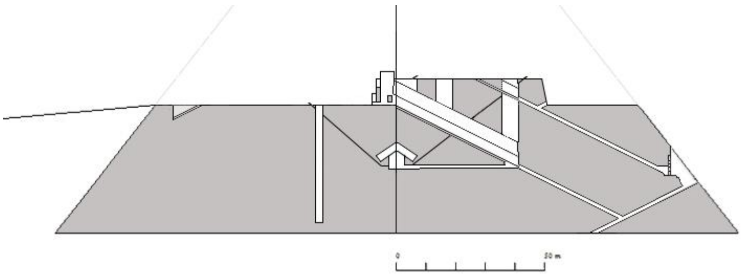
The latest version of the GG2 and its position above the GG1 now takes into account an important element that was foreseeable: the extension of the ascending corridor in the lower part of the GG2 connects perfectly with the SP-NFC corridor discovered behind the entrance rafters. Again, this is not by chance, but the result of a precise plan. Finally, the entire GG2 set extends from the East-West axis to the plumb of the North wall of the GG1.

[267] As in the case of the Sinai sand that was found in a 30 cm thick cavity near the horizontal corridor during three drillings, spaced 1.50 m apart, carried out by the EDF mission in 1986/1987. Composed of nearly 95% quartz, this sand has a low density, between 1.4 and 1.6, and is very fluid; it must have had a precise function.

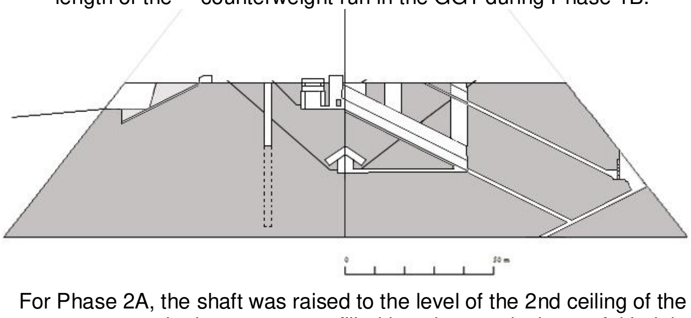


The GG2 measures a minimum of 40m, it is located in a zone between +50m and 70m and the extension of the ascending corridor for the movement of the roller train tension ballast-roller leads behind the rafters of the entrance, exactly where the corridor named SP-NFC was discovered.

In the last update, further improvements to the counterweight system were made, again due to a greater understanding of the designers' intentions and their constructive logic. Thus, the principle of the "motor"[268] associated with the counterweight of the GG2, was now applied for the counterweight of the GG1, allowing to eliminate the human force in Phase 2A and to reduce it considerably in Phase 1B.



Construction of the[269] motor well for the GG1 counterweight system began at bedrock level, about 20 meters south of the GG1. Its height corresponds to the length of the[270] counterweight run in the GG1 during Phase 1B.



For Phase 2A, the shaft was raised to the level of the 2nd ceiling of the superstructure; the lower part was filled in to keep only the useful height.

[268] The three portcullis-lests in the well above the Portcullis Chamber.
[269] The "motor" of the GG1 was composed of three portcullis-lests weighing 3.5t each (1.18m x 0.52m x 2.10m or 1.29m3 x 2.7). Later, they will be shortened of one cubit (0,52m) to be reused for the motor of the GG2.
[270] That is to say, about forty meters high.

<u>*Information note N°4*</u> *:*

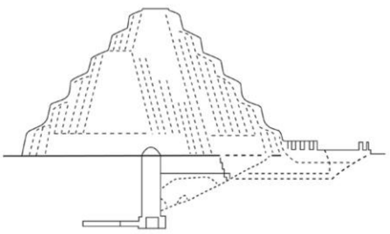
At the beginning of Chapter 3 - THE PROBLEM OF THE CONSTRUCTION SITE OF THE KING'S CHAMBER, *I took a sentence from the fourth paragraph of the Preamble:*

"... I was already totally convinced that at the time the architects had designed the project by imagining two distinct building sites integrated one into the other: on the one hand the volume itself, on the other the King's Chamber and its superstructure".

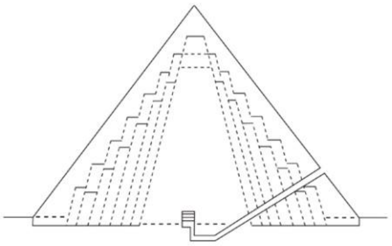
After having written: "The solution they applied to the site had a name: Counterweight", I specifically developed this second site by relying on the presence of the Grand Gallery in the heart of the pyramid, a work out of the ordinary in the architecture of Ancient Egypt, objectively unrelated to a funerary function; on the other hand, for a builder, it is a very significant work.

Thus, before going any further, it seems important to me to go back in time, to the moment of the conception of the construction project of the Great Pyramid and to give my vision of the interaction between the two building sites, that of the volume and that of the King's Chamber. Although the design of the latter was to be carried out independently, it was conditioned by the technical processes implemented for the construction of the former; the entire interior architecture of the pyramid was to be dependent on the choice made by the designers to offer King Khufu a flat ceiling for his burial chamber.

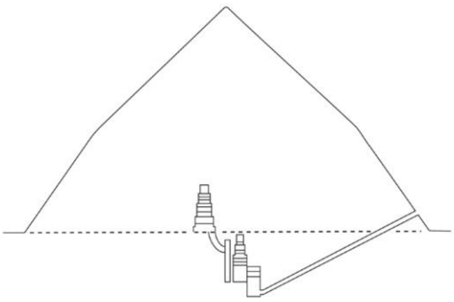
The ScanPyramids mission would never have discovered the BIG VOID if the designers had used, for the King's Chamber, the technique implemented after the Djoser pyramid to cover the burial chambers and the antechambers: the load-bearing vault known as the corbelled vault.



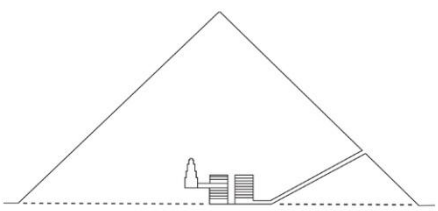
The Pyramid of Djoser at Saqqara:
The burial chamber is at the bottom of a well of about thirty meters covered by a dome-shaped vault.



The pyramid of Huni in Meïdum:
The burial chamber is dug into the bedrock but its cover is a corbelled vault.



The Bent pyramid of Snefru in Dahshur South:
the funerary chamber, set on the ground and built in the mass of the pyramid, is covered with a corbelled vault.
The antechamber dug in the bedrock is also covered with such a vault.



The Red Pyramid of Snefru in Dahshur North:
the funerary chamber, at about ten meters height, and its two antechambers, set on the ground, are built into the mass of the pyramid and covered with corbelled vaults.
Sketch Albert Ranson

Everything I have written so far would simply not be necessary.

But the facts are there, the King's Chamber was built as we know it and its position, forty-three meters high in the pyramid, is certainly not linked to chance, let alone to an architect's whim.

The first reason is certainly to be found in the architectural evolution of the position of the previous burial chambers, first at the bottom of a well at Saqqara, then "coming out" of the bedrock and finally rising into the pyramidal volume with the Red Pyramid. On the other hand, all these pyramids had a common point; they had been designed to require only human strength in all the stages of their construction.

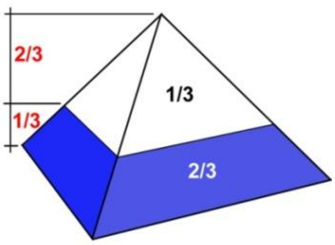
The second reason is related to the choice of material for its construction: Aswan granite. Between the difficulties of its extraction, the number of monoliths required and the distance of the transfer to the construction site by the Nile according to the floods, many years were going to pass before being able to start the construction. The pyramid did not wait and the ideal level of +43m to "put down" the King's Chamber had been chosen because several factors played in its favor:

- The topography of the Giza Plateau made it possible to build a ramp from the port to the base of the external ramp[271] which rested on the South face of the pyramid in the southwestern corner, both ramps having an average slope of 8 to 9%.

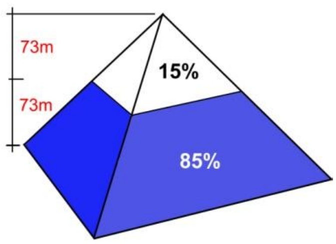
- The extension of the external ramp in a trench reserved in the body of the pyramid and rising[272] to the level +73m, half-height of the pyramid, in a spiral parallel to the faces, thus leaving a great part of the center completely free, allowed to build up to 85% of the volume without ever disturbing the construction of the King's Chamber.

- The opening of the third section of the internal ramp[273] in the southwestern corner[274] at the level +43m, with a direct access to the ramp in trench, allowed the setting up of a "temporary detour" of the transit of the Turah limestone facade blocks during the construction of the first two ceilings above the King's Chamber.

In summary, the construction processes of the volume were reserved for the internal periphery of the pyramid and that of the construction of the King's Chamber and its annexes developed in a narrow strip a few meters east of the North-South axis. The ramps/slides of the counterweight system, in opposition on both sides of the East-West axis, were in the direction of the slopes of the facades, although less steep. The northern part was integrated into a temporary mastaba-type building, which was drowned in the mass of the pyramid at the end of the construction.

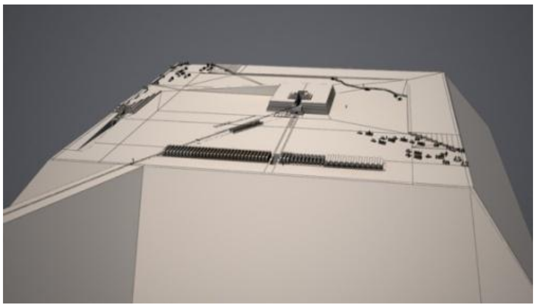


A constant that the Egyptians must have noticed: Whatever the slope of a square-based pyramid, at one third of its height there is already two thirds of its volume. The ceiling of the King's Chamber is exactly one third of the height.

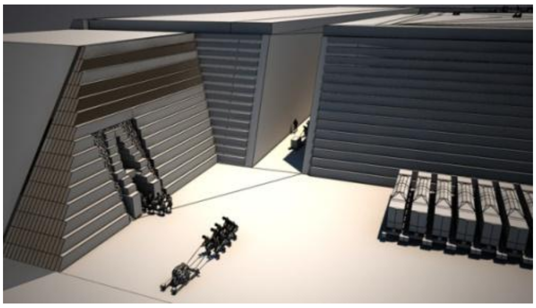


85% of the volume could be realized thanks to the short external ramp and its extension in trench which allowed reaching the level +73m, half height of the pyramid; at this level the roof of the King's Chamber is completely covered.

271 See C - Third Era, 2011 to November 2016 Page 17.
272 In a clockwise quarter-turn spiral.
273 It rose in a counter-clockwise quarter-turn spiral between the trench ramp and the faces of the pyramid.
274 In the article "Microgravity probes the Great Pyramid" published in January 1987 in the journal Geophysics: The leading edge of exploration, Jacques Lakshmanan and Jacques Montluçon, directors of the 1986 EDF mission, write: ""*We feel that the lower southwestern part of the pyramid could be heavier*…". I imagine that this area could have been reinforced to better handle the temporary additional load from the external ramp**.**



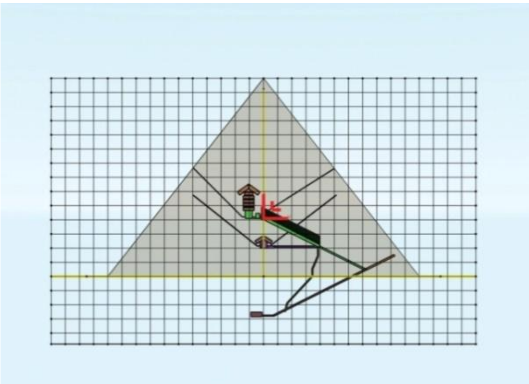
The external ramp arrived at the +43m level in the same southwestern corner as the 3rd section of the intenalr ramp. The storage area for the monoliths was centered along the South face, on the place of the future 4th section which will be horizontal, the ascent resuming with the 5th section.



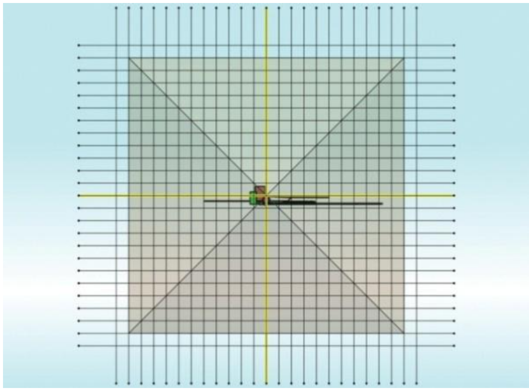
Intersection in the southwestern corner between the external ramp, its extension in the pyramid trench and the outlet of the 3rd section of the internal ramp.
Its course will be temporary diverted by the ramp in trench during the construction of the first two ceilings.

Now, for the design of the project, the Egyptians did not have 3D at their disposal, but they still had to imagine in space. Fortunately, they could simply materialize the works in the volume in 2D, by transferring them on a horizontal and a vertical plane. And to locate each component in space, they used a system of orthogonal grids based on the unit or a multiple of that unit as needed.

Thus, the volume of the pyramid is based on a global grid in multiples of 20 cubits[275] : a base of 22 x 20c = 440c for a height of 14 x 20c = 280 c and a ratio of 14/11[276] (22/2=11) at the apothegm. This grid was centered on the North-South[277] and East-West axes, thus marking the diagonals; in a few indications, the design of the volume was completed. All these elements allowed the control of the elevation of the pyramid all the more easily as the façades were free of any obstacle.



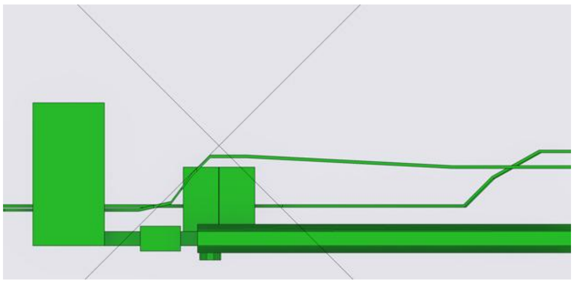
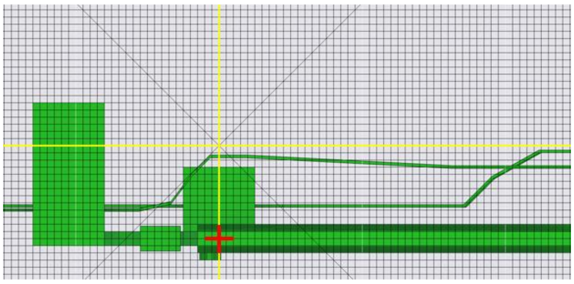
Vertical plane with the main grid of 20 cubits square.
In yellow the vertical axis and in red the point of origin of the entire project design in the vertical plane.



Horizontal plan with the main grid of 20 square cubits. In yellow the North-South and East-West axes. All the structures built inside were positioned in relation to these two axes.

As for the interior structures, they will be designed and transcribed from a fine grid of one square cubit drawn within the overall grid but only in the area where all the structures in the pyramid will be built: a strip along the North-South axis about 30 cubits wide, offset towards East by 13 cubits. The precision of the Grand Gallery, the chambers and the corridors, ascending, descending and horizontal, results from their immediate proximity to the axis.

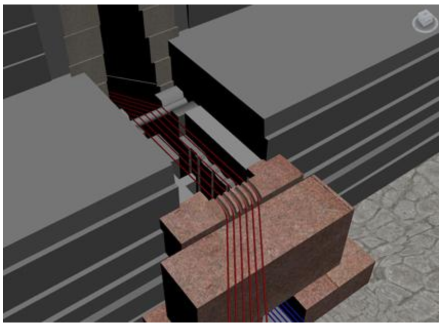
[275] The Egyptian units were the royal cubit (c) divided into 7 palms, each palm being itself divided into 4 fingers. There were thus 28 fingers in a cubit which measured 0.524m.
[276] This gives a slope angle of the facades of 51.84°.
[277] Hence the importance, among other things, of defining this axis, at night from the North Star and verified by gnomons at the zenith, during the implantation of the pyramid; the East-West axis was traced from the North-South axis by arcs of parallel circles traced on both sides of a same point. The crossing of the arcs created a succession of points allowing tracing the East-West axis.

To be able to build the King's Chamber at +43m height fourteen years after the beginning of the construction site, everything had to be determined in advance. This chamber was a "box" of 20c x 10c x 11c to be positioned in the volume of the pyramid. Thanks to the system of grids, it was perfectly spatially fixed.
Because of the choice to cover it with a flat ceiling, the Egyptians were forced to integrate the Grand Gallery into the project, as it determined the spatial position of all the other structures built in the volume.
The main 20c square grid is white, the secondary 1c square grid is black and the N-S and E-W axes are yellow.
The red cross indicates the point of origin of the entire project design in the horizontal plane.

The GG1 measures 82c in horizontal projection and has a vertical drop of 41c in vertical projection, giving it a slope of 50% (1 for 2), or 26.5°.
The zero point of the entire design is located:
- In the vertical plane, on the edge formed by the ground and the face of the "upper platform" of the GG1, the face being aligned on the East-West axis and the floor being at 82c[278] from the base
- In the horizontal plane, the GG1 axis is offset by 13c towards East regarding to the North-South axis.

This point was chosen as a reference for the siting of the GG1 in order to concentrate the construction process of the King's Chamber as much as possible in the center of the pyramid. Moreover, it was close to the extension of the axis of the external ramp, which formed an angle of about 30° with the axis of the GG1. A construction detail of the North wall of the King's Chamber is very significant: for the tractions of the monoliths in Phase 1B, the traction ropes coming out of the GG1 were deflected by 30° at the level of this wall, which was still under construction, to end up in the axis of the external ramp. To withstand the enormous forces concentrated on this deflection point, the Egyptians did not hesitate to put in place two huge granite blocks, with a height of two normal rows, and for a total weight of about 70 tons. This detail will have an influence on the height of the outlet[279] of the shafts in the King's Chamber: to remain in the same vertical alignment as those of the Queen's Chamber, the North shaft will be carved in the corners of the two blocks of the first row[280] of the wall supporting these two mastodons, the South shaft facing it.




Details of the deviation of the ropes coming out of the GG1 for the traction of the monoliths in Phase 1B. With their total weight of about 70 tons, the two granite blocks in the North wall of the Chamber withstand the concentrated forces at the point of deflection, allowing the ropes to be placed in line with the external ramp. The deflection grooves could have been cut in a block of red basalt that was inserted in the block of the second row overlooking the Portcullis Chamber.[281]

[278] The floor of the upper platform is at +42,96m from the base, i.e. exactly 82c from it. The floor of the King's Chamber is at +43,00m from the base, i.e. an offset of 4cm.
[279] The importance of this detail will be explained later in this document.
[280] On the other hand, those of the Queen's Chamber are in the upper part of the blocks of the 2nd row.
[281] A detail could support this idea: in its upper part, this block has a recess in the granite that was filled in with a limestone block before the roof of the Portcullis Chamber was laid.

While taking advantage of the Plateau topography, the external ramp position, near the southwestern edge of the pyramid, following an angle of about thirty degrees to the South face of the pyramid, had a direct consequence on two parameters: the King's Chamber location and the construction of its North wall, with the two blocks of granite weighing approximately 70t in total

Consequence: Determined by the position of the GG1 in relation to the external ramp, the position of the King's Chamber is 82c from the base and its North wall[282] *is 16c south of the East-West axis. It is off axis, its West wall being 6c west of the North-South axis and its East wall 14c east of this axis.*

From the zero point and a slope of 1c for 2c, it was easy to determine the route of the ascending couloir and the GG1. Thus, around the 4th or 5th year of the construction site, the workers began the construction[283] *of the ascending corridor at 19c*[284] *from the base and at 126c to the north of the East-West axis, tracing its axis at 13 c from the North-South axis.*

Finally, in addition to the design by grid, the Egyptians made models of the sensitive points: junction of corridors for example. This is why they made a model dug into the bedrock about fifty meters east of the pyramid. This model is still there and gives us indications on their way of working, like details[285] *on the corridors and their junction.*

Conclusion: If the position of the interior structures was directly influenced by the construction processes of the volume, their realization[286] *was totally independent of the construction of this volume; a simple but very effective conception of two distinct building sites integrated one in the other.*

[282] The interior faces of the walls of the Chamber.
[283] The lower part of the ascending corridor, between this level and the descending corridor, is not built, it is dug in a reconstructed base of Turah limestone for technical reasons: to tighten the side walls of the corridor in order to slow down and stop the fall of the granite plugs and to treat the junction with the descending corridor in a simple way. During the previous centuries, the Egyptians had acquired great experience as "sappers" by digging galleries and underground tombs.
[284] About 10.00m from the base and 66.00m north of the East-West axis.
[285] One of which, curiously, is not reproduced in the corridors visible today. The discovery of the SP-NFC behind the rafters of the entrance could change this.
[286] As in any construction site, there may be dimensional differences between the design plans and what was built in reality. The plans available to us (Maragioglio & Rinaldi and Gilles Dormion) must be considered as a recollection plan based on the dimensions taken. That said, the intentions of the designers are perfectly legible.

Going back to my interpretation of the BIG VOID discovery, the integration of the GG2 into my earlier proposals is straightforward. I imagine that in the early sketches of the counterweight system to be implemented in the pyramid, the designers, based on the known laws of physics[287] at the time, deliberately opted for simplicity and efficiency, even if it meant integration of large[288] structures.

The project design therefore focused on the following overriding objectives:

- Do the tractions with the 180° return technique for the construction of the ceilings and the roof,

- Brake the run of the counterweight(s) for a smooth and controlled traction,

- Keep the ropes parallel to the slope or limit the β angle to a minimum if it is unavoidable,

- Minimize the friction of the ropes on the returns-relays by limiting their deviations and their number,

- Eliminate or minimize the friction of the counterweight trolley(s) and the hoisting platform,

- Modulate the load of the counterweight(s) according to the beam to be towed,

- Rearm the counterweight(s) to its base load,

- Eliminate the use of human force en masse, keeping it only if needed to assist the counterweight system punctually and in a reduced way.

In the following pages, I have reconstructed a series of hypothetical schematics that the designers must have had in mind when defining the counterweight system for the 180° return technique traction[289] implemented in the pyramid.

After having well posed the problems, broken down the sequences, determined the heights of the ceilings-struts, calculated the lengths of the runs of the moving elements of the system and minimized the friction at the various places, they went to this conclusion: the system had to be divided into two overlapping components and three successive Phases had to be set: Phase 2A using the GG1 and Phases 2B1 and 2B2 using the GG2.

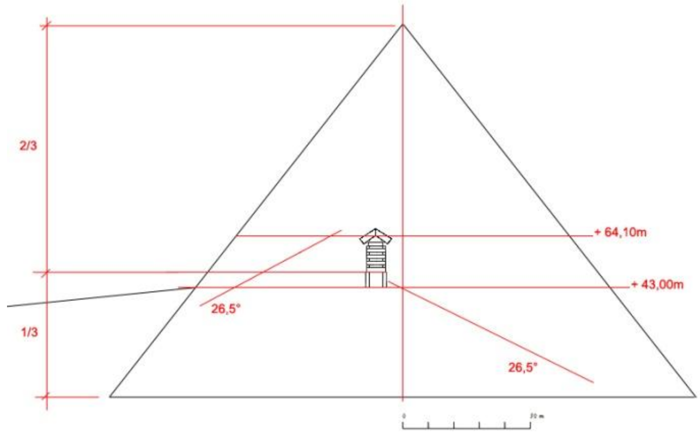
They then positioned the "motors" and the extraction and removal wells for the counterweight overloads.

The only thing left to do was to design the structures for the slides and their ancillary structures, with a basic assumption: the hoisting platform would remain outside in the southern side and the counterweights would circulate in gallery tunnels in the northern side.

Phase 1B, the rise of the monoliths on the storage area at level +43m, required that the first slide be integrated into the pyramid and emerge in the upper part at this level; that said, the run length of the counterweight of this Phase 1B was formally based on that of Phase 2A.

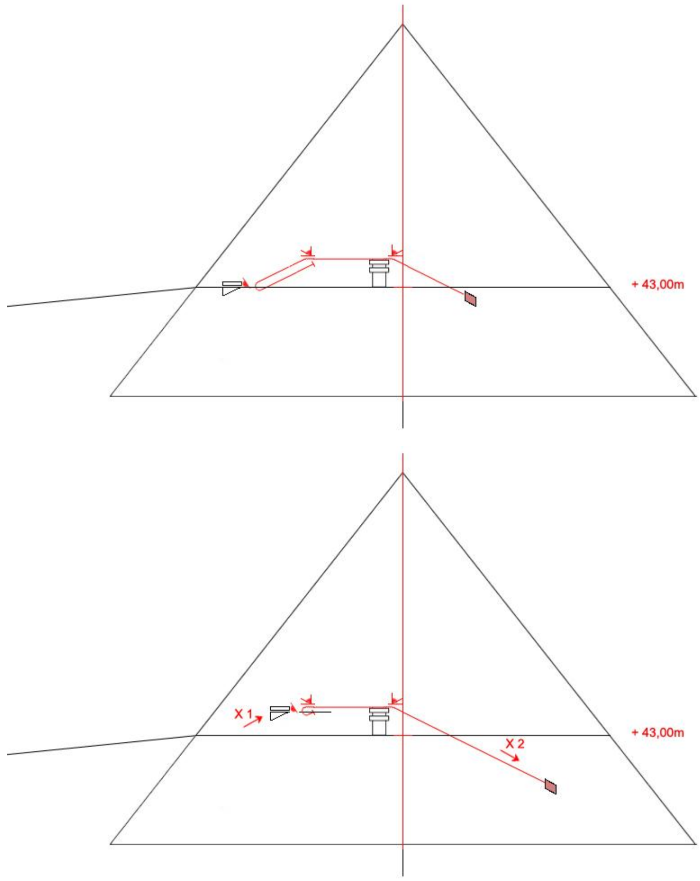
On the other hand, as explained in Case N°1 on Page 10, the difference in slope between the tractor and the towed allowed direct traction of the monoliths, the latter moving with each traction of the run length of the counterweight; therefore requiring half as many tractions as if the 180° return technique would have been used.

[287] Acquired during their experiences in the Art of building for several centuries.
[288] The GG1 and the GG2 being the most remarkable.
[289] Requires half the traction force but twice the length of the slide for the counterweight



The geometric constraints imposed in the specifications of the King's Chamber project are summarized in this sketch.
The architectural design of the counterweight system inside the pyramid had to satisfy these.
The characteristics for an optimum performance of the system, based on the laws of physics known at the time, determined the number of main structures and their annexes to be created, their shapes and their positions.

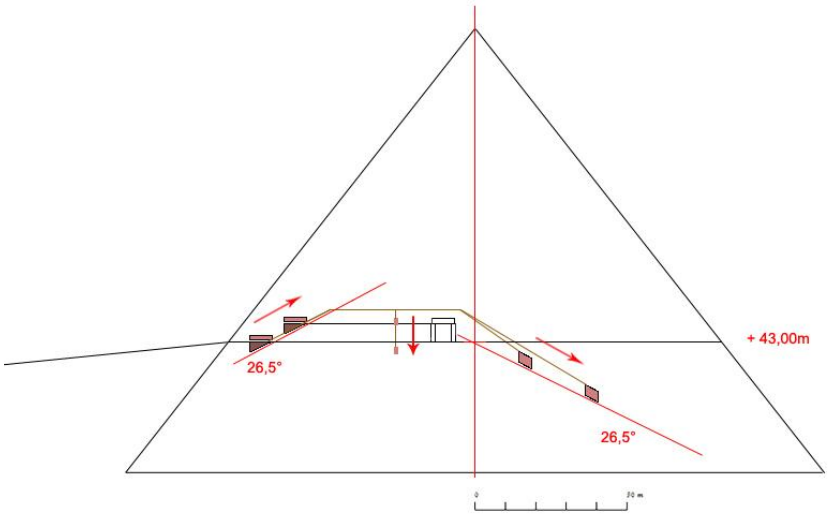
Principle of traction with 180° return[290] implemented in Phases 2A, 2B1 and 2B2.

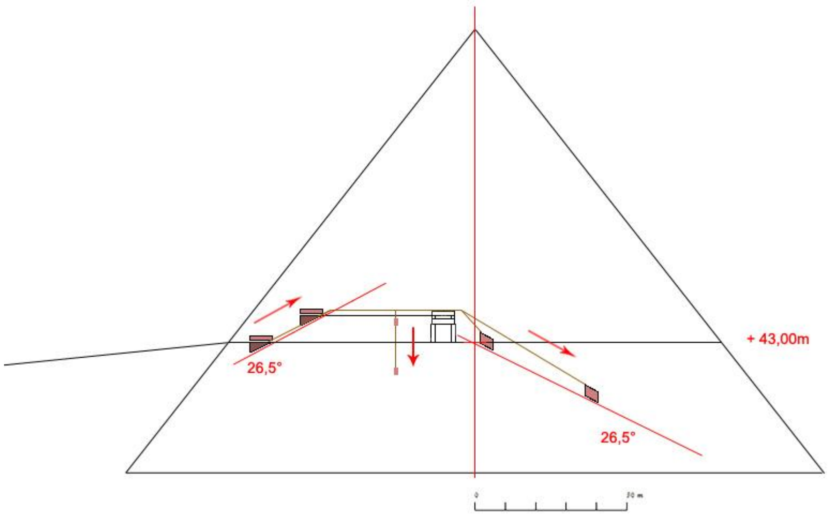


The traction ropes are anchored in the upper part of the slide on which the monolith hoisting platform runs; from there, these ropes make a u-turn at the front of the plateform before joining the counterweight moving in a gallery on the opposite side.
As a result, the run length of the counterweight is twice that of the monolith.
The relays on the path are indicated: in this example at the level of the 2nd ceiling, a 180° one at the front of the platform, a 63.5° one in the upper part of the slide and another 63.5° one in the upper part of the gallery.
The counterweight and the hoisting platform each run on a "rollers-train" moving on each slide, de facto removing friction.

[290] Which I also call proto-palan.

Diagrams Phase 2A: the building of the ceilings 1, top, and 2, bottom, using the GG1.





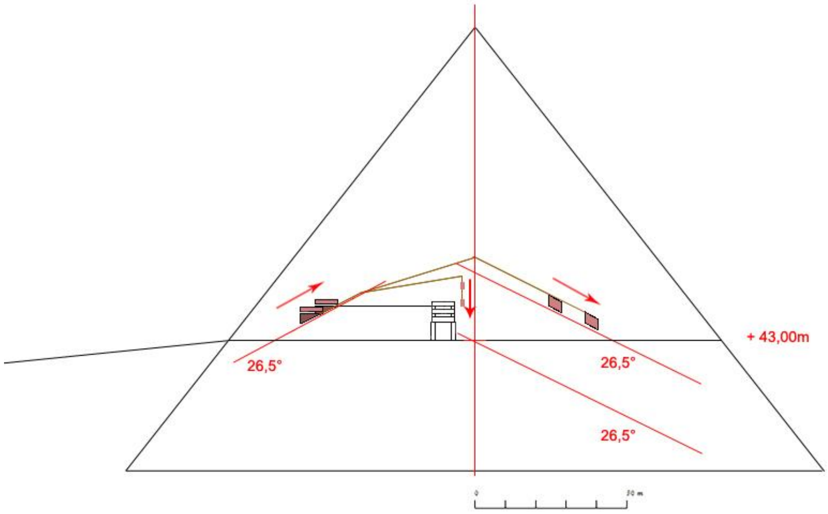
One 180° return at the front of the transport platform and two 63.5° relays at the top of the slides: hoisting and the GG1. The counterweight run is twice that of the platform; the very small β angle created by the ropes in the GG1 is favorable when pulling and unfavorable when rearming, but offset by the modulation of the counterweight load. On the other hand, it is obvious that the GG1 would soon reach its limits of effectiveness due to the angle β[291] increase as the upper ceilings were built. The height limitation[292] of the beams of the first two ceilings is due by the need to pass the beams of ceiling 2 under the traction ropes during their setting.

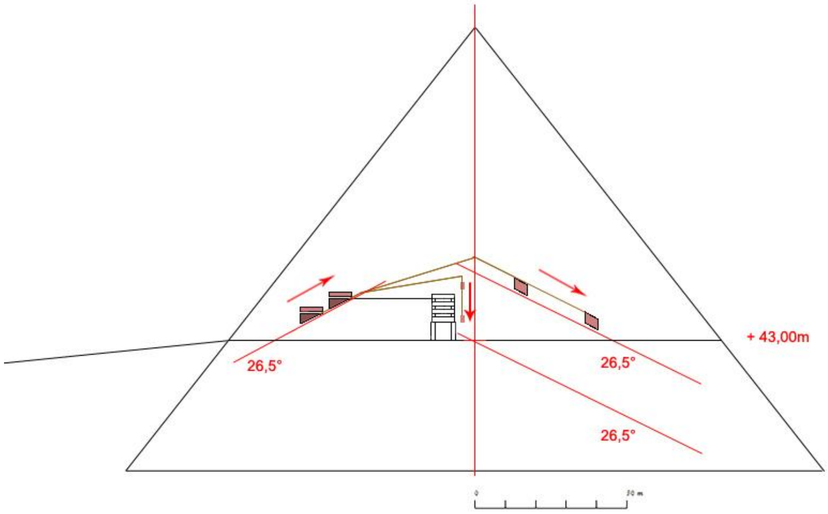
A well for the "motor" is built between the hoisting slide and the King's Chamber.

The controlled run down of the counterweight is achieved by braking the descent of the "motor".

291 Being fully aware of the problem for having been confronted to it until the discovery of the BIG VOID.
292 See 4th paragraph and following Page 22.

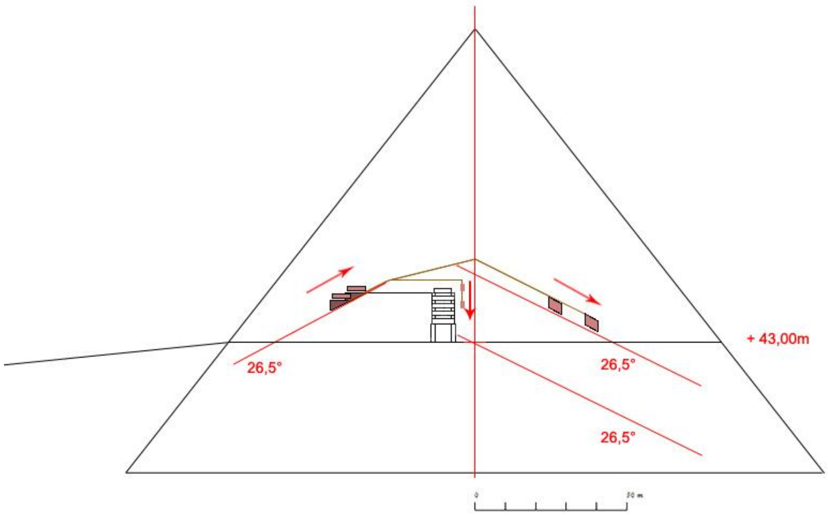
Diagrams Phase 2B1: the building of the ceilings 3, top, and 4, bottom, using the GG2.

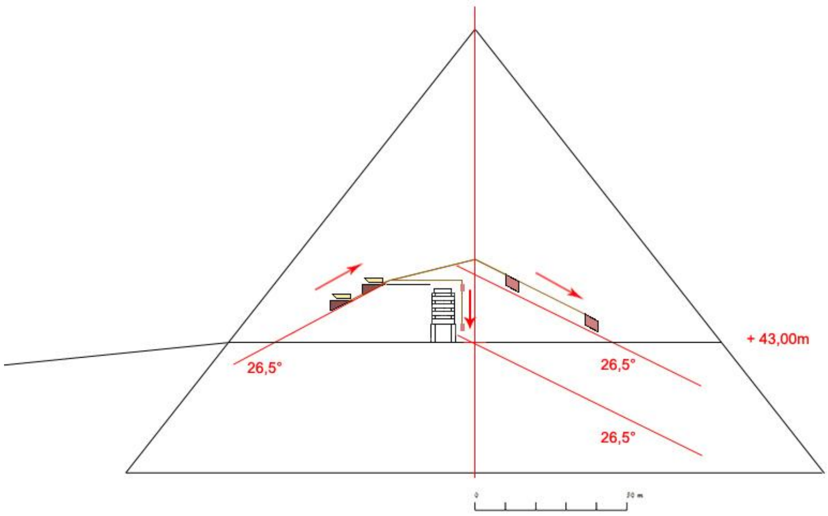




One 180° relay at the front of the hoisting platform, one 122° relay on the East-West axis between the hoisting slide and the GG2 and one 5° relay at te top of the hoisting slide. The height of the beams doesn't matter, the ropes passing much higher. A well for the "motor" is built between the GG1 and the GG2 and the King's Chamber, above the Portcullis Chamber.

Diagrams Phase 2B2: the building of the ceiling 5, above, and the roof, below, using the GG2.

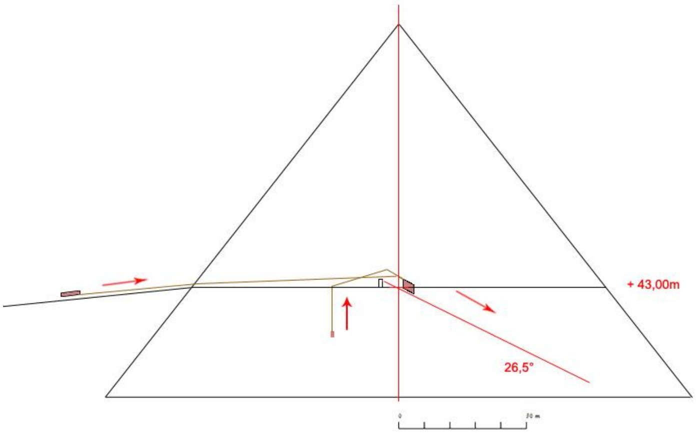


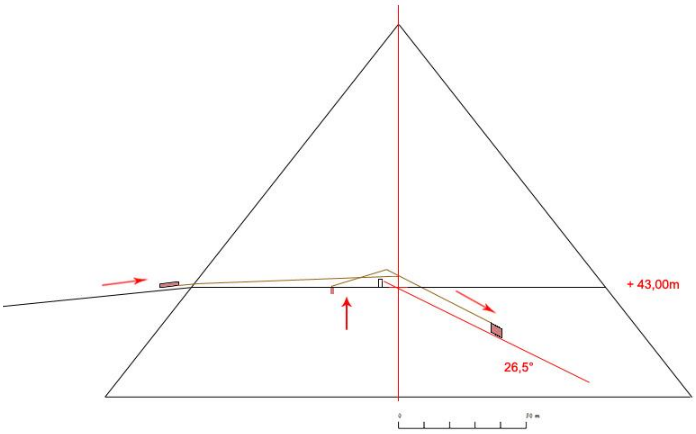


The configuration is identical to that of Phase 2B1 since it is a repetition of the latter from the level of the ceiling 4. The only difference is the increase in the[293] run of the counterweight in the GG2 to reach the +64.10m level.

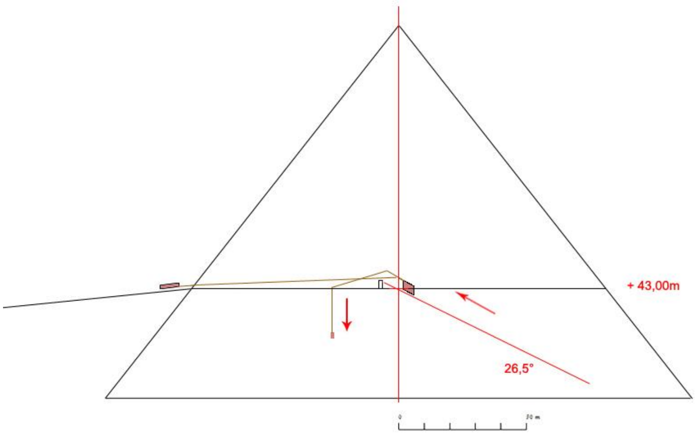
[293] See cross-section plans at the top of Page 26.

Diagrams Phase 1B : the hoisting of the monoliths on the storage area at the level +43,00m.





The characteristics of the GG1 being fixed for Phase 2A, the counterweight moving inside it has a run length of almost 40m, pulling, thanks to a direct traction, the sled carrying the monolith over the same distance .
Unlike the following Phases, thanks to the difference in slopes, the "motor" is not used to tow the monolith but to rearm the counterweight. During each traction, the counterweight hoists the monolith and pull up the motor. The counterweight at its basic load is used to pull up the motor and the overloads modulation is used for the towing of the monoliths. Depending on the weight of each monolith, the overload varies from seven to nine blocks. For the towing of the heaviest monoliths[294], the system is assisted by human force in small numbers: two teams of twenty men, positioned at level +43m on either side of the motor well, pull up using the proto-palan technique, one or two portcullis-lests.
This relieves the traction of the counterweight, the force thus being transferred directly to the towing of the monolith.



After each traction, a segment[295] of the ropes of the length traveled is withdrawn; the motor moves up the counterweight at the top of the GG1 for a new traction. The sled is tied again to the ropes for another pull.

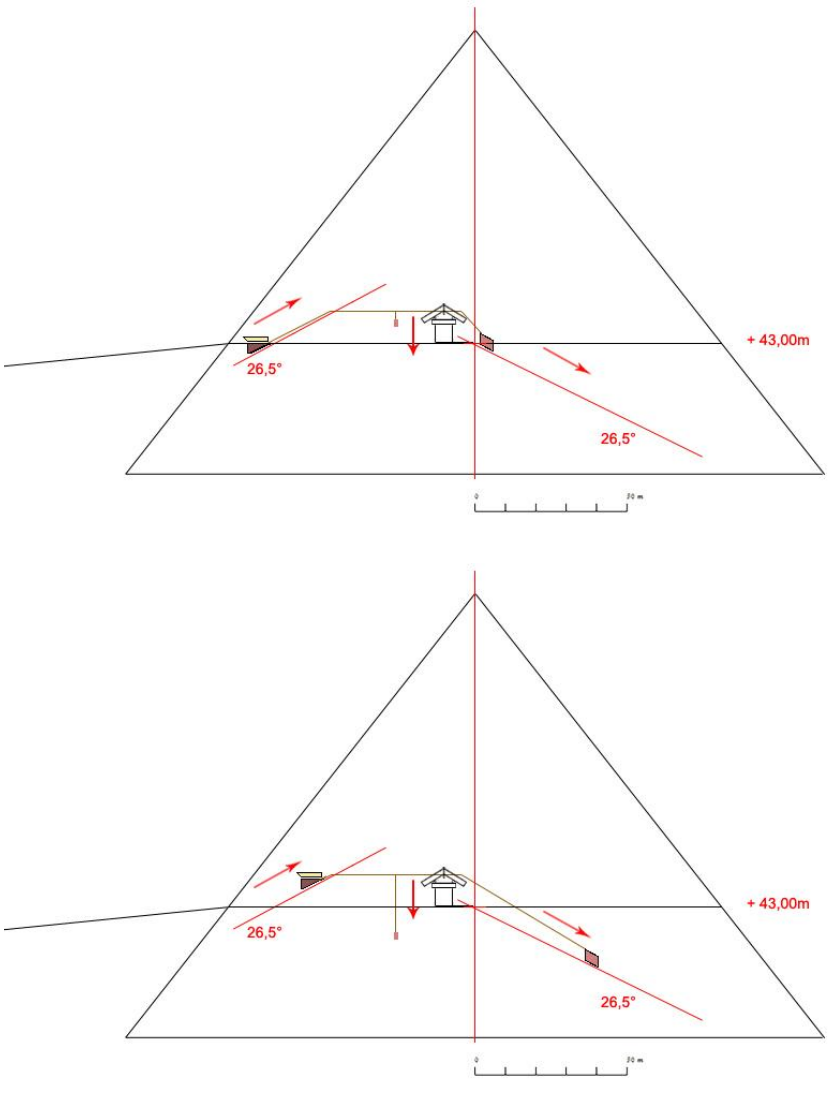
294 For monoliths weighing 50t and more, i.e. in only eight cases. See information note No. 2 Page 32
295 As in a "surveyor's chain".

Important note:

Looking at these diagrams, one observation becomes obvious: the King's Chamber could have had the same flat granite ceiling and been covered by a rafter roof of Turah limestone laid directly above. It would have been perfectly protected by this roof, as well as by the one placed above the 5th ceiling. Its ability to bear the load above is proven by the Queen's Chamber and its unique roof of the same type.

In this case, the Grand Gallery would have been necessary for its construction, but this solution would have simplified the building site enormously.

If the designers put in four ceilings-struts plus a roof, resulting in the construction of the GG2 and its annexes, it is because they had a very specific and very important reason.[296]



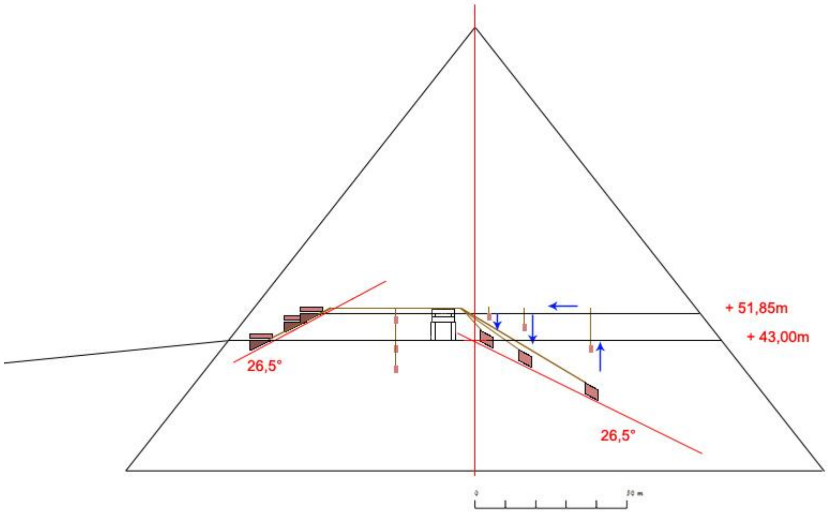
With the GG1 alone, the King's Chamber could have had the same flat granite ceiling and been covered by a rafter roof of Turah limestone laid directly over it.

[296] This point will be treated in the forthcoming document: "Khufu's Pyramid, recent discovery of a corridor under the North face by the ScanPyramids mission".

With all these parameters set, all that remained was to determine the position of the wells for the modulation of the counterweight load by taking the run lengths of the different sequences of each Phase and the position of the counterweights.

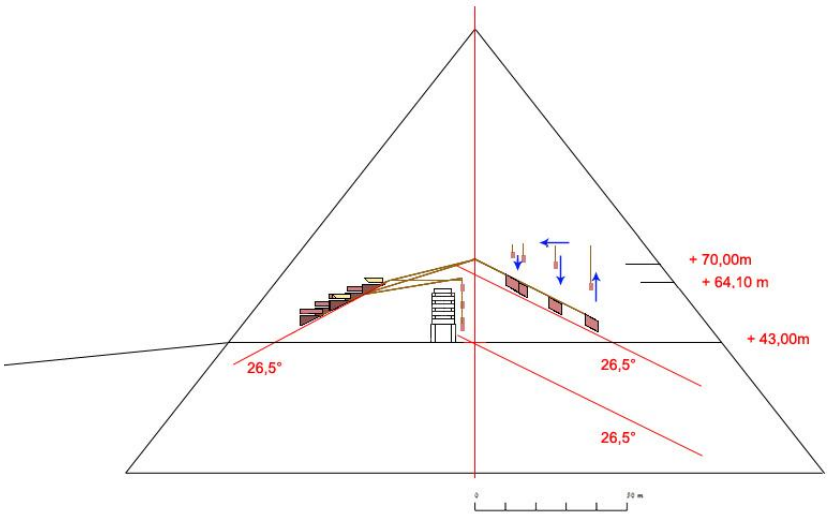
For Phases 2B1 and 2B2 serving four levels of the superstructure, the rhythmic distribution of ceiling and roof heights built in two successive sequences was justified; it allowed the construction of a shorter GG2 and reduced the number of wells needed from 4 to 3, as for the GG1. Its height position, about twenty meters above the floor of the GG1, was essential.

Schematic of Phase 2A, fixing the position of wells above the GG1.



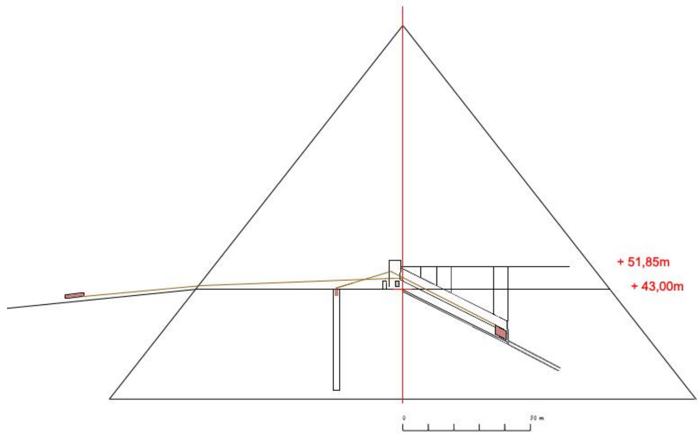
The 1st well, at the bottom of the GG1, is plumb with the counterweight in the low position; the 2nd well, intermediate, is plumb with the counterweight for the traction of the beams of ceiling 1; the 3rd well, at the top of the GG1, is plumb with the counterweight for the traction of the beams of the ceiling 2.

Diagram of Phases 2B1 and 2B2, fixing the position of the wells above the GG2.

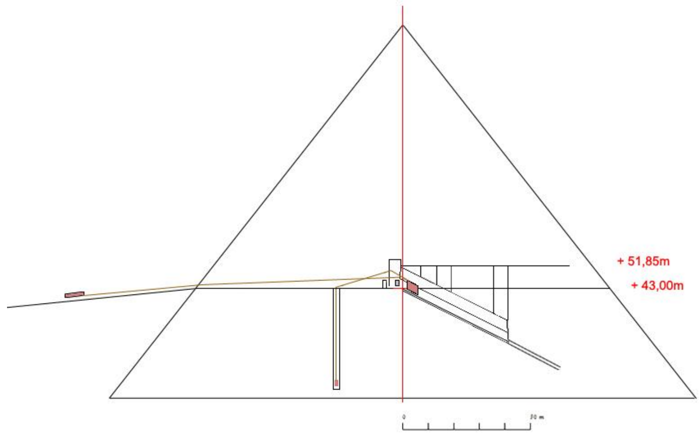


The 1st well, at the bottom of the GG2, is plumb with the counterweight in the low position; the 2nd well, intermediate, is plumb with the counterweight for the traction of the beams of ceilings 3 and 5; the 3rd well, at the top of the GG2, is plumb with the counterweight for the traction of the beams of the ceiling 4 and the roof.
These three wells are each time centered on the counterweight; the first two measure 6.00m in length, the 3rd is designed for two positions of the counterweight and measures 12.00m.

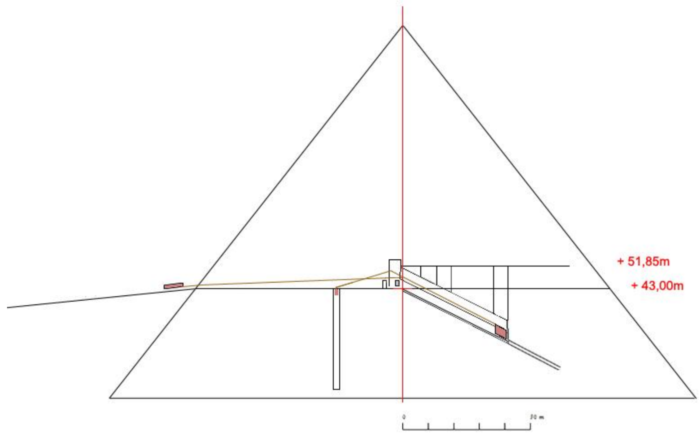
The architecture of the structures needed for the project could then be built around these diagrams, with the designers having a well-established specification[297] . The one for Phase 1B is very simple.



The structures required for Phase 1B are the GG1, built with its three wells, the ascending corridor and a well about forty meters deep about twenty meters south of the King's Chamber, in line with the GG1.
The motor is only used to rearm the counterweight.



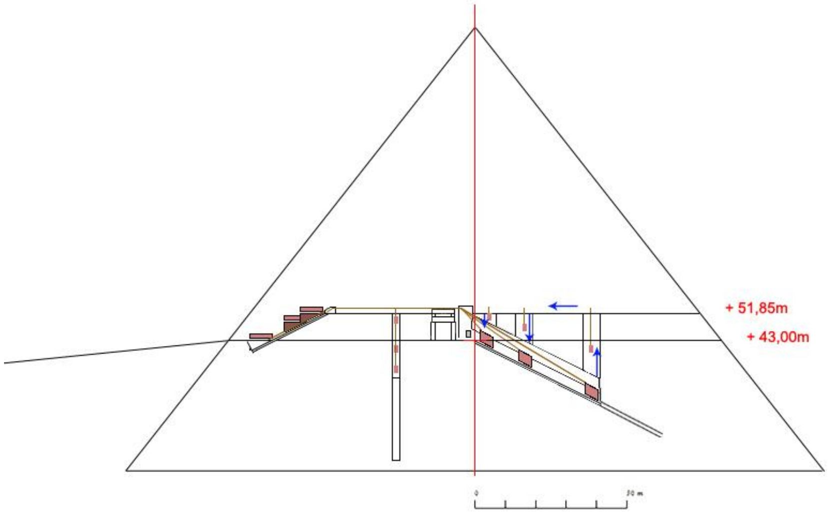
In Phase 1B, the modulation of the traction force is done by overloading and unloading the counterweight through the extraction wells built above the GG1. For beams over 50t, the force produced by two teams of about twenty men is necessary to raise a part of the motor.
These teams are positioned at the +43m level on either side of the motor well.

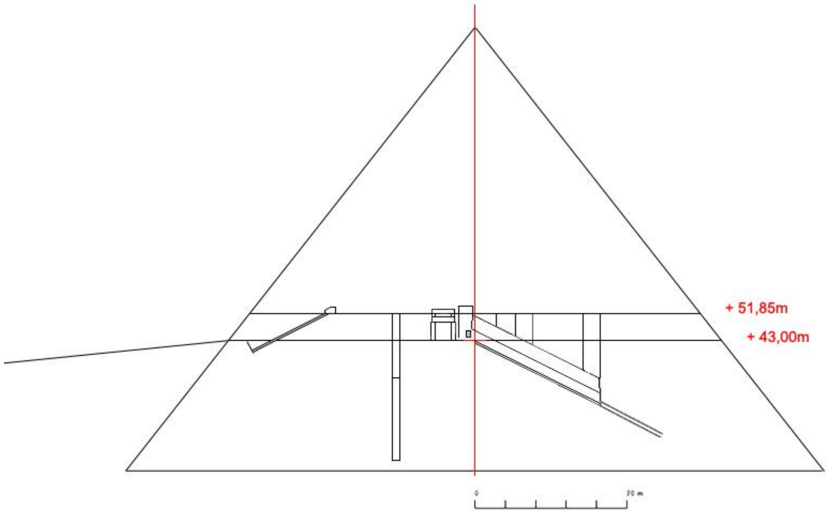


Phase 1B is the only one that directly uses human force to pull monoliths over 50t.
In all phases, the strength of about twenty men is required for the modulation of overloads.

[297] In a modern construction project, the specifications contain all the constituent details of the work to be built and are appended to the plans.

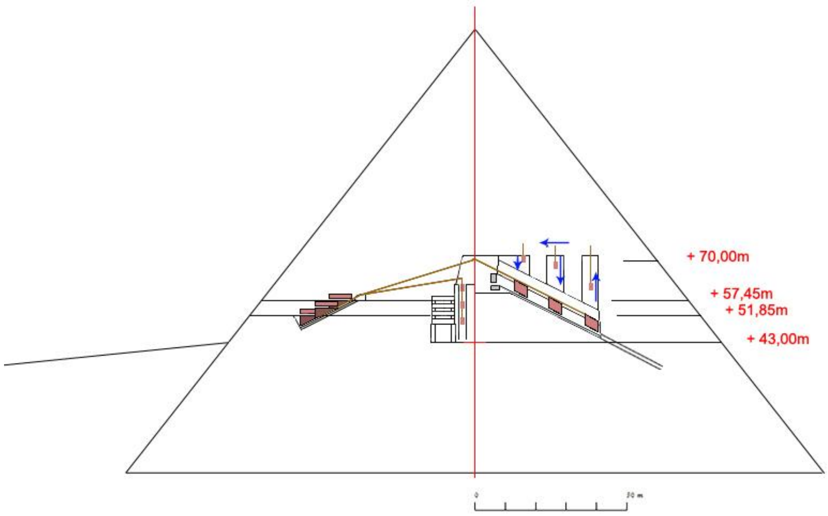
Architecture of Phase 2A structures.

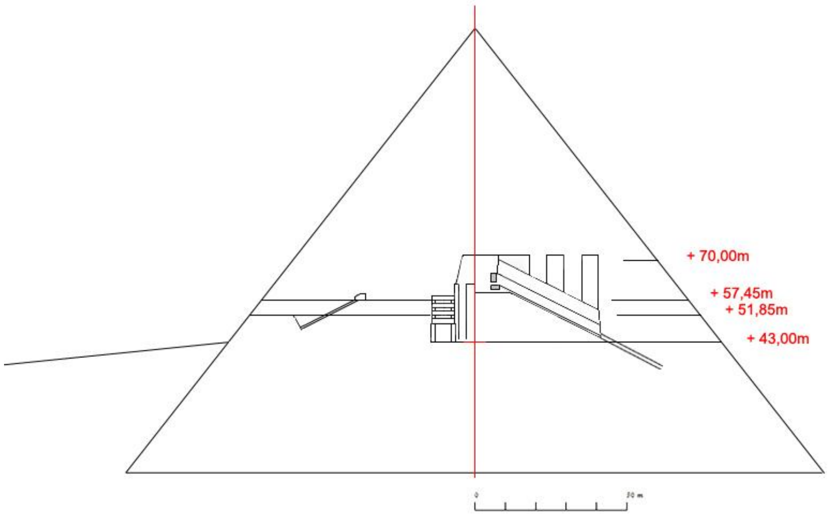




Construction of ceilings 1 and 2.
The three wells are focused on the three positions of the counterweight in this phase.
They measure 6.00m in length.
The motor well is raised to the +51.85m level and a lower part used in Phase 1B is filled in.
In contrast to the GG1, external ramp-slide is built from level +43.00m to level +51.85m.
It has the same characteristics as the lower part of the GG1, except that the rollers-train tension roller-lest runs directly under it;
the height of the side benches is greater so as to leave more space.

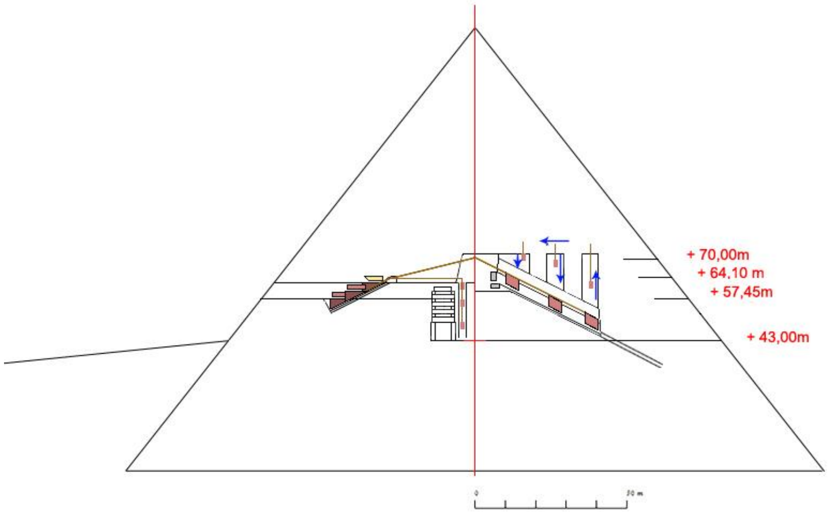
Architecture of Phase 2B1 structures.

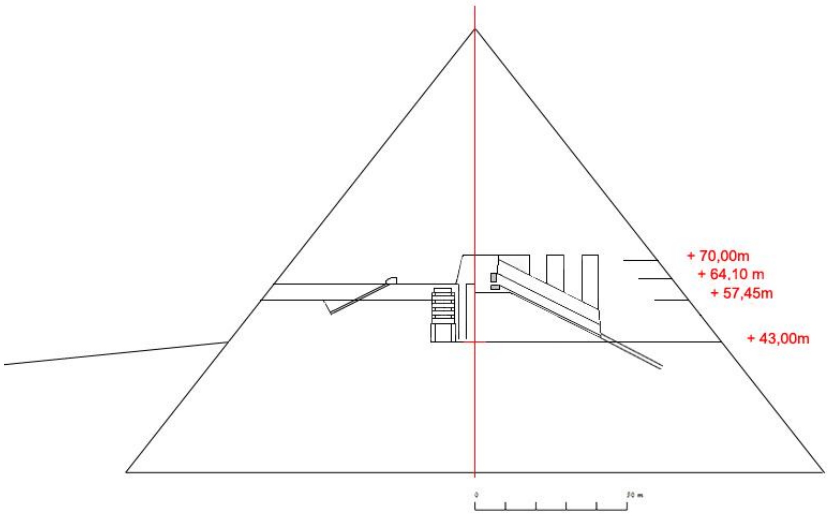




Construction of ceilings 3 and 4 with the GG2..
The three wells focus on the three positions of the counterweight in this Phase.
The lower and intermédiate wells are 6.00m long, the upper one is 12.00m long.
The counterweight stops under the lower part of this well.
The motor's well for Phases 2B1 and 2B2 is entirely built above the Portcullis Chamber.
The well of Phase 2A is filled.
Opposite the GG2, the external ramp-slide is built up to level +57.45m; on the other hand, it is filled between level +43.00m and level +51.85m.

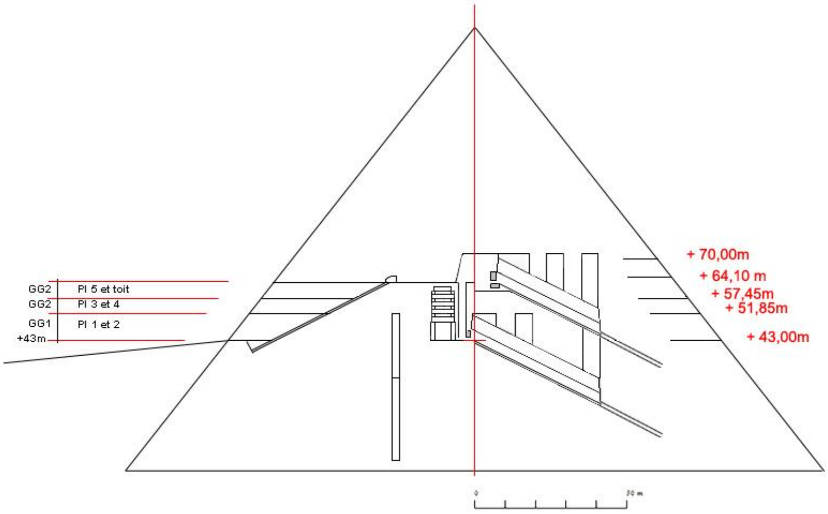
Architecture of Phase 2B2 structures.



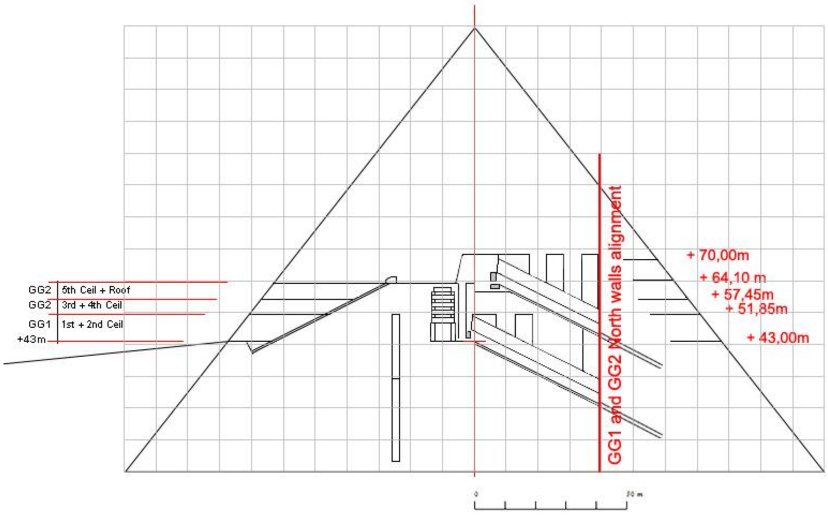


Construction of ceiling 5 and the rafters roof with the GG2.
The three wells are focused on the three positions of the counterweight in this Phase.
The lower and intermediate wells are 6.00m long, the upper one is 12.00m long.
The counterweight stops under the upper part of this well.
The motor's well for Phases 2B1 and 2B2 is entirely built above the Portcullis Chamber.
The Phase 2A well is filled in.
Opposite the GG2, the external ramp-slide is built up to level +64.10m; on the other hand, it is filled between level +51.85m and level +57.45m.

By combining the two galleries of the counterweight system, the GG1 and the GG2 with their ancillary structures, the interior architecture of the pyramid takes shape.



The design philosophy of the counterweight system inside the pyramid can be summarized in a few lines:
To use the 180° return technique for all the ceilings and the roof, i.e. a height difference of 21.10m, a slide ensuring a minimum travel length of 70.00m for the counterweight trolley was needed; the length of the trolley (approximately 5.50m), plus a margin for lengthening the ropes (approximately 2.00m) and finally a platform in the upper part (approximately 2.00m) had to be added, which would have resulted in a gallery of nearly 80.00m long.
This gallery would have started flush with the bedrock!
With a notorious handicap: from the 3rd ceiling, the increase in the angle β of the traction ropes would have required the use of human force en masse.



The simpliest solution: divide and conquer.
The gallery was split into two parts, the first (the GG1) serving ceilings 1 and 2, the second (the GG2) serving ceilings 3, 4 and 5 plus the roof, each optimally positioned for the 180° return technique. This split had an added benefit, the longer length of the GG1 reduced the number of tractions on the external ramp.
The designers, having drawn the GG1 from the Zero Point at the top of it, chose to refer to this same point by creating a new Zero Point for the GG2 on its North wall inside face.
They set it on a vertical alignment axis drawn from the inner face of the North wall of the GG1.
They then drew the structures on either side of this axis, the GG2 going up and the Ascending Corridor N°2 going down towards the base. Thanks to the design grid, all that remained was to set this point in height so that the upper platform of the GG2 was horizontally in alignment with the highest level to be served, level +64.10m.
As a result, the GG1 and the GG2 have their North wall in perfect alignment.
This split had a cost, the lengthening of the GG2 to take account of the counterweight trolley and the upper platform.
On the other hand, the lengthening of the ropes did not change, the total run length being the same, being redivided between the GG1 and the GG2.
The GG2 is at least 38.04m long from wall to wall, plus a horizontal technical room that must be added in the upper part, between the motor well and the South wall; the whole void extend between the East-West axis and the alignment axis of the North walls, i.e. a distance in horizontal projection of 41.36m, or 79 cubits, identical to that of the GG1 between these two axes.

The rearmament technique of the counterweights in Phases 2A, 2B1 and 2B2.

The modulation of the load of the counterweights running in the GG1 and the GG2 in Phases 2A, 2B1 and 2B2[298] is not only very effective for hoisting the monoliths, but is essential for their reset before any traction; thanks to it, the counterweight system can work in all cases.

Indeed, as already seen, the 180° return traction technique implies a double run length of the counterweight compared to that of the platform carrying them. This, once the monoliths have been delivered to their setting levels, is empty; it can therefore be used to rearm the counterweight[299] by being sufficiently loaded with granite blocks[300] like the ones of the Portcullis Chamber[301]. This idea is simple and logical, but problems arise:
- The traction force of the platform would be divided by two if the ropes remained in the 180°[302] return traction technique arrangement.
- The run length of the slide/ramp would require rearming the counterweight in four round trips[303] of the platform.
- The motor could not be rearmed because of its run length, which is twice that of the platform, whereas it was supposed being used to rearm the platform prior any new traction.

The Egyptians had already implemented a segmented traction technique for hoisting the monoliths in Phases 1A and 1B; a segment was detached after each pull to shorten the line[304] of traction as the sleds advanced. They applied the same concept for the line of traction between the counterweight and the hoisting platform; the length of line needed to implement the 180° return was a made of detachable segment that could be replaced by a special segment allowing a direct traction. The latter restored full traction force to the platform solved the problem of rearming the motor and reduced the reset of the counterweight to two round trips.

But with direct traction a new problem occurred: if the counterweight system had a fixed-load and capable of hoisting the heaviest beam[305], the platform had to be loaded 1.6 times more than the weight of that beam, not counting the simultaneous rearmament of the motor; an unrealistic solution. By creating modulation of the counterweight load through the overload extraction and removal wells, the designers also solved this problem. By reducing the weight of the counterweight to its base weight[306], the platform became capable to reset the counterweight and the motor by being loaded with seventeen blocks of 2.5t, or approximately 42.5t[307]. This weight corresponds to the average weight of the monoliths transported, and the footprint of three rows[308] of overload blocks placed longitudinally fits perfectly into the dimensions of the platform; this one could therefore be easily loaded for the rearmament of the counterweight and the motor.

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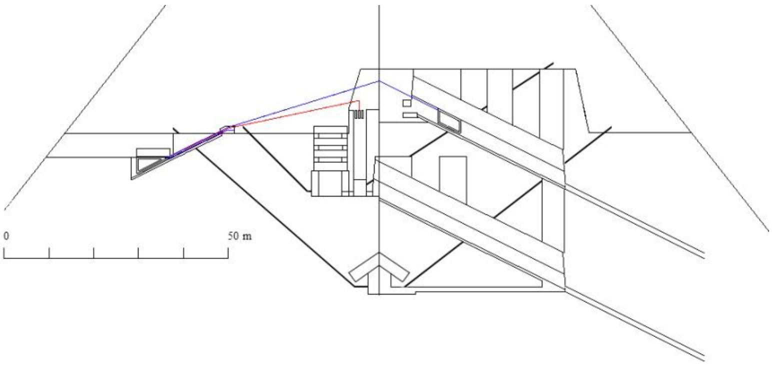
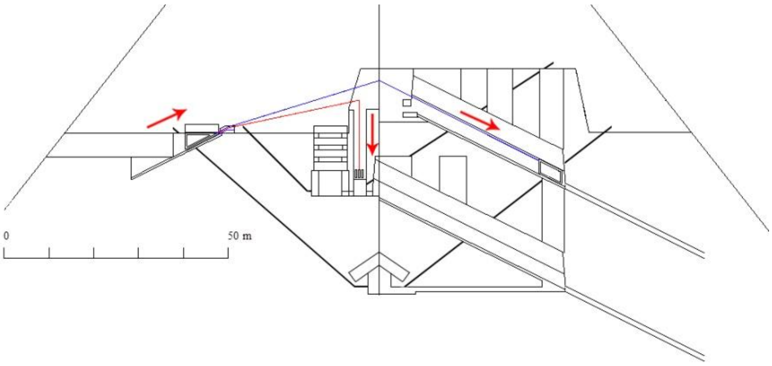
298 The technique of rearmament the counterweight in the GG1 during Phase 1B has been illustrated in the diagram at the top of Page 65, this one being specific to this Phase.
299 Thus becoming the counterweight of the counterweight in use.
300 Blocks of about 2,5t, therefore relatively easy to transport.
301 See footnotes 180 and 181 Page 31.
302 I.e., keep the arrangement of the ropes identical to that of the monoliths hoisting.
303 The platform run length divided by 2 for a doubled run length on the opposite side.
304 On the port ramp, the multi-ropes traction line (4 to 6 depending on the weight of the monolith) was divided into sixteen segments of about 39.00m long – see 2nd paragraph Page 16
305 A 62t beam of the 1st ceiling – see *Information Note N°2 Page 32*
306 I.e. approximately 19.15 tons based on the weight of the three granite plugs blocks and the trolley frame.
307 Plus the weight of the platform frame, 2t, for a total of 44.5t
308 7.08m (1.18m long x 6) and 1.77m (0.59m wide x 3) to be compared to maximum dimensions for the beams: 7.33m long and 2.20m wide.

Diagrams of the counterweights rearmament in Phases 2A, 2B1 and 2B2.

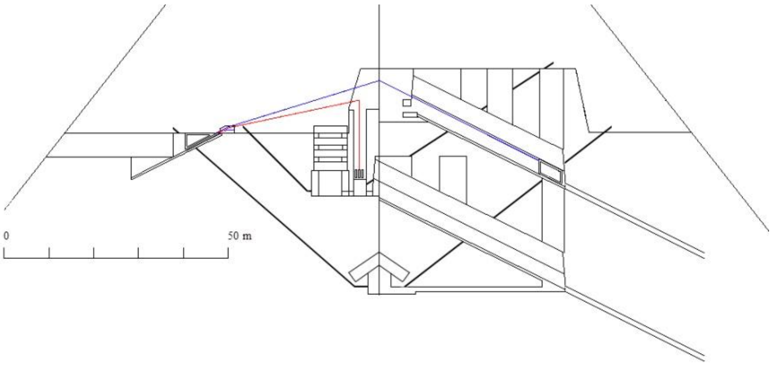
Example: the hoisting of a 4th ceiling beam with the GG2 followed by the reset of the counterweight.



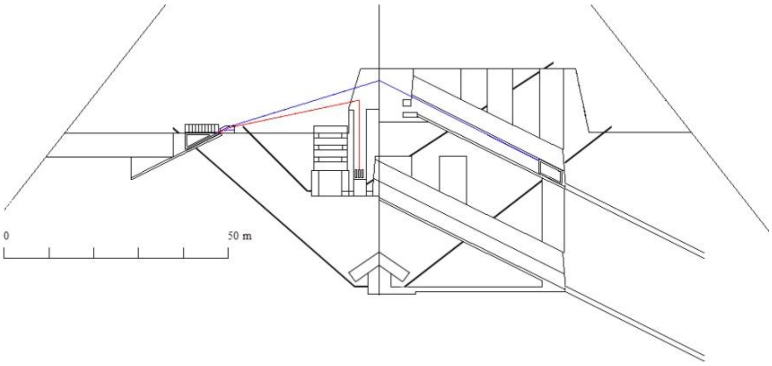
On the left, the beam is on the platform in the low position. On the right, the counterweight is in the high position for a 180° return technique traction. In the center, the motor is in high position.



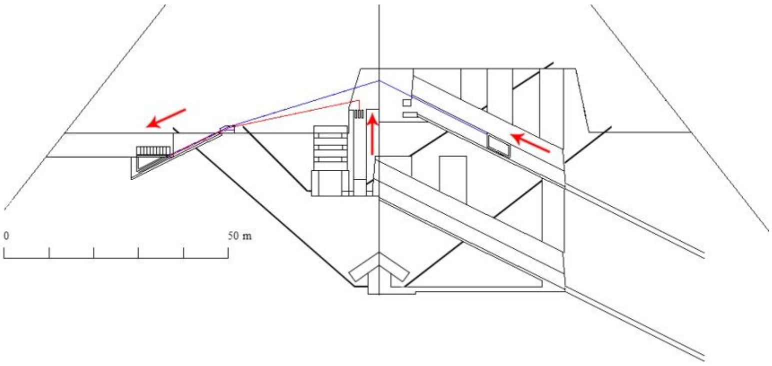
After the traction, the beam has reached its delivery level. The counterweight and the motor are in the low position.



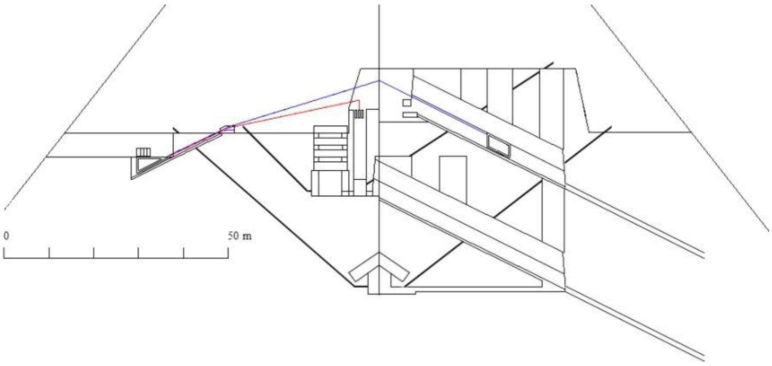
The beam was unloaded; the line of ropes was modified, a first short segment linked to the 180° return technique was removed from its attachment and replaced by another short segment adapted to the direct traction technique. The line of ropes was kept in tension at the top end of the platform ramp-slide during the maneuver.



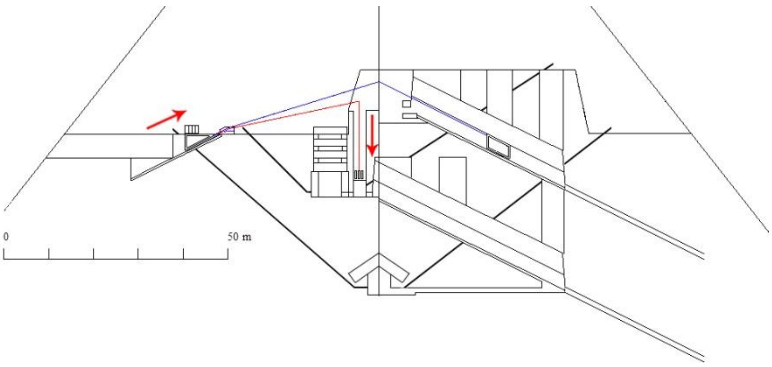
The platform is now loaded with the seventeen 2.5t blocks needed to rearm the counterweight and the motor.



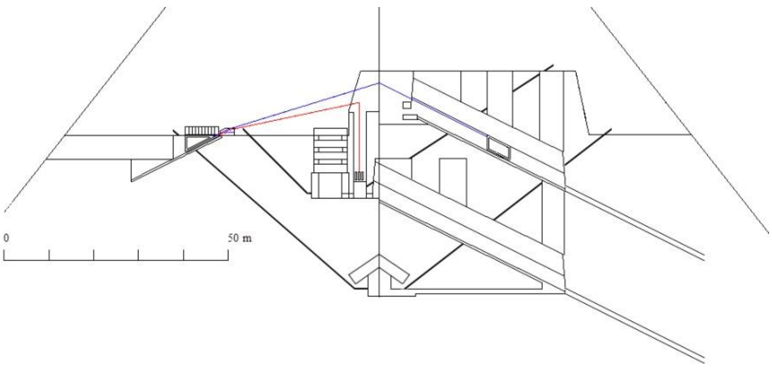
The first traction of the rearmament is finished; its run was slowed down by a team holding the platform.
The counterweight is at the halfway point of its reset; the motor is in the upper position.



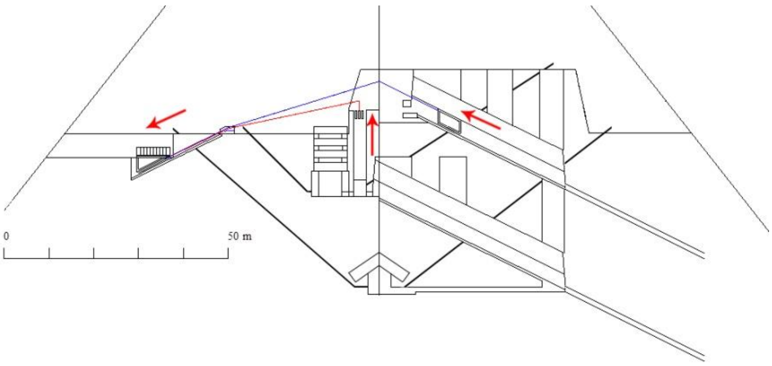
A large part of the load is removed from the platform, while the load that can be pulled by the motor is retained.
The line of ropes connecting the counterweight is fixed at the level of the upper platform of the ramp-slide.
A second segment linked to the 180° return technique between the platform and the upper end of the ramp-slide is removed to shorten the line of traction accordingly. The platform is hoisted, towed by the motor alone.



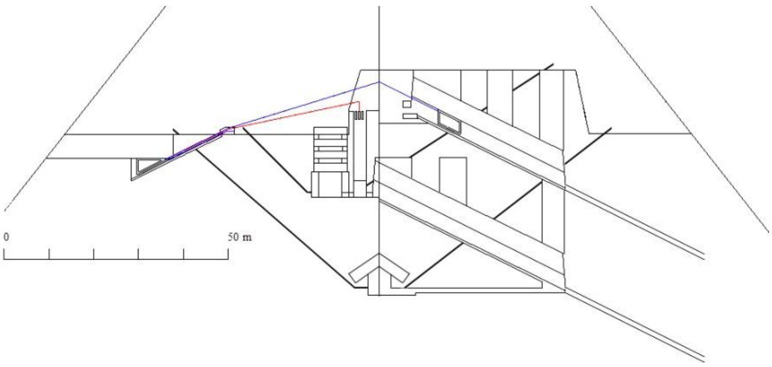
The platform is in the upper end of the ramp-slide, the motor is in the lower position. The counterweight rearmament ropes line is again connected to the platform at the temporary attachment, this line being shortened by the length of the previous run.



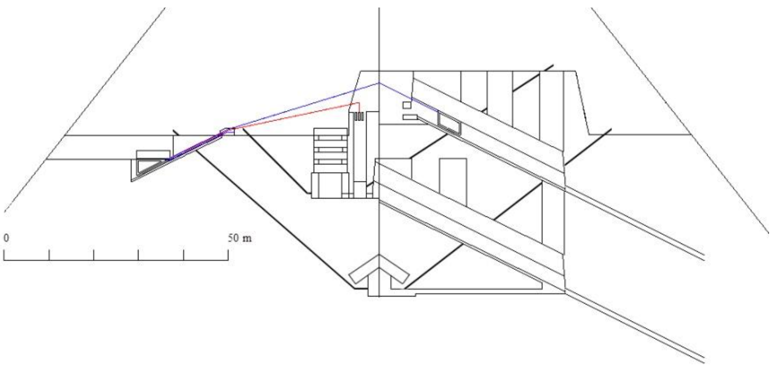
The platform is once again loaded with seventeen 2.5t blocks.



The second traction of the rearmament is over; its run has been slowed down by a team holding the platform. The counterweight and the motor are in the upper position.



The platform is unloaded, the segment of the ropes line for direct traction is removed, the two segments for traction by 180° are put back in place. During this operation, the motor is used to release the tension of the ropes of the traction line by acting on the hoisting platform.



Once the rearmament is completed, a new beam is loaded on the platform for a new 180° return technique traction.

To end with this counterweight rearmament procedure, it is worth to put this operation in the context of the construction site, the hoisting Phases of the monoliths and the notion of time.

I imagine it took until the end of year 14[309] of the reign to get all the monoliths on site[310] and another year for Phase 1B to be completed. Phases 2A[311], 2B1[312] and 2B2[313], requiring a total of one hundred and forty-three tractions, could have been spread over a minimum of three years, which indicates that these operations were not hastily done, but in a controlled execution schedule.

[309] See 2nd paragraph Page 16.
[310] Phase 1B having probably started around year 13, some of which was already hoisted onto the storage area.
[311] 65 tractions for the setting of first two ceilings with the GG1 and the hoisting of the remaining monoliths up to the level of the 2nd ceiling.
[312] 48 tractions for the setting of ceilings 3 and 4 with the GG2 and the hoisting of the remaining monoliths up to the level of the 4th ceiling.
[313] 30 tractions for the setting of the 5th ceiling and the hoisting the roof beams with the GG2.

<u>Information note N°5 :</u>

Looking at all these diagrams, one thing is clear: the distances between the different areas of the site are very large. For example, more than 110m horizontally and nearly 9m vertically between the storage area at level +43.00m and the top of the northernmost well of the GG1; more than 90m horizontally and nearly 18m vertically between the base of the ramp-slide and the top of the northernmost well of the GG2. Phase 1B involved nearly six hundred tractions and Phase 2A, sixty-five. As for Phases 2B1 and 2B2, they required seventy-nine tractions in total. These figures are to be multiplied by two with the rearmament of the counterweights. In addition, these last three phases required precise preparations regarding the modulation of the load of the counterweights accordingly to the weight of the beams to be hoisted; and particular attention during the movements of the counterweights and the platform in order to prevent any technical incident. It is not by communication by gestures or by flags[314] that this problem could be solved. Here again, the Egyptians must have found a simple and very effective solution.

From the beginning of my research about Khufu's pyramid, while reading Jean Kérisel's[315] book, "KHEOPS, Genie et Démesure d'un Pharaon", I was struck by a paragraph[316] which was engraved in my memory and is always present in my works. This is about the King's Chamber (translated from french):

"Before entering this room for the first time, an incident occurred in the electric lighting circuit; suddenly the pyramid was in the dark as Muslims in the King's Chamber chanted their prayers. At the top of Grand Gallery, the sound I was hearing was extraordinary in its purity and breadth. I entered the room to find, lit by a single candle, that there was only one Muslim prostrate in a corner near the sarcophagus: extraordinary amplification".

I immediately understood that this amplification[317], linked to the granite which is the only material of the Chamber, had been exploited by the builders for one reason or another. Then, in 2001, during a meeting with Pierre Delétie[318], I spoke to him about the acoustics of the Chamber. He then told me about his personal experience that took place during the microgravity mission; while he was in the King's Chamber, he could perfectly hear colleagues talking to each other, thinking that they were in the Portcullis Chamber. He moved to talk to them, but there was no one there or in the Grand Gallery. He went back to where he had come from and as he passed next to the North shaft of the Chamber, he realized that the voices were coming from outside, more than seventy-five meters away. He then called out to his colleagues and a conversation ensued. He was absolutely amazed!

Looking into the problem, I realized that the Queen's Chamber also had extraordinary acoustics: its Turah limestone walls were sanded and polished, which had the effect of increasing the acoustics; for me there was an obvious desire to use this acoustic.

Shortly thereafter, I devised the counterweight system for hoisting the beams and associated it with an intercom system based on the Queen's Chamber and its two shafts, which do not open to the outside,

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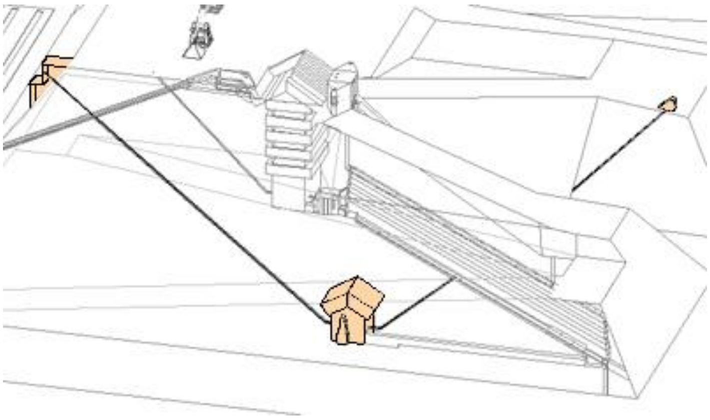
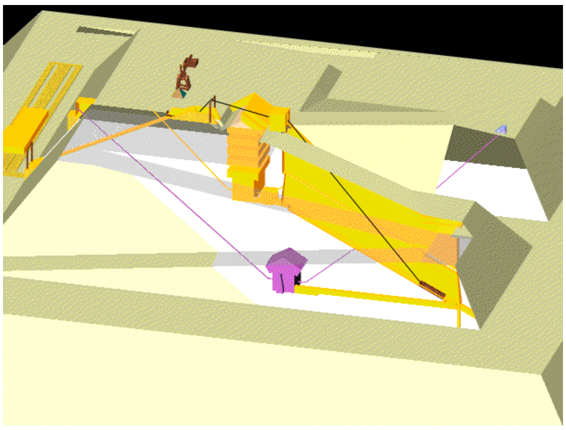
[314] That kind of suggestions I have often had the opportunity to read in comments regarding my proposals about communication. Why not by…billows of smoke!
[315] Jean Kérisel, a friend of my father, is at the origin of my work on Khufu's pyramid.
[316] Pages 126 and 127
[317] Later, the Greeks built a "heptaphone" in Olympia, proof that the Ancients were skilled acousticians.
[318] Pierre Delétie is the geologist who was part of the EDF Foundation's microgravimetry mission; he was the one who gave my father and me documents on this mission in September 2000.

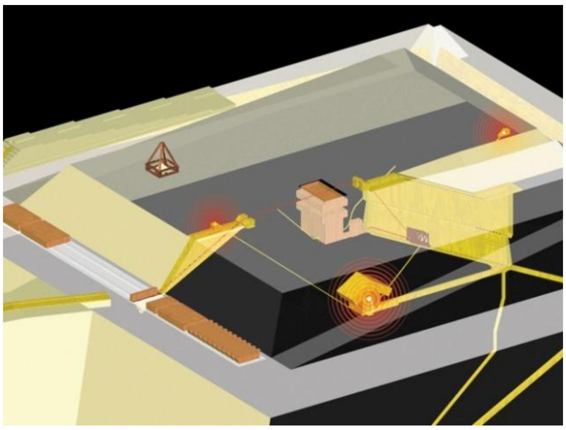
and one of which was sealed by a limestone slab[319]*. The construction of the Queen's Chamber*[320] *was intended by the designers as a backup burial chamber in case of the King's untimely death; it would have taken over from the subterranean chamber if the King had died before the construction of the King's Chamber was completed. That said, as with many structures in the pyramid, it had another temporary role: to be an acoustic chamber for the intercom system. Its position, centered on the East-West axis, made it possible to build, at a similar angle, two acoustic shafts starting from the North and South walls and opening at equal distance from the latter as the pyramid rose. Their position was precise, their outlet in the room facing each other, and their course remained as close as possible to the North-South axis, although the North shaft had to be diverted to avoid structures built in this part.*

Since 2002, the intercom system has been central to the operation of the counterweight system; at first, to my great regret, it was solely based on the Queen's Chamber, having difficulty finding a role for the King's Chamber despite its better acoustics. The discovery of the BIG VOID has totally changed the situation; the role of acoustic amplifier of an intercom system involving the two chambers is now indisputable evidence when analyzing the geometry of the shafts. This one is surprising because, in all the Phases, they emerge near a structure involved in the counterweight system.



First 3D model of the intercom system based on the Queen's Chamber in March 2002.
On the left, the outlet of the South shaft allows you to have an overview of the ramp-slide for hoisting the monoliths; on the right, ditto too for the outlet of the North shaft, for an overview of Grand Gallery. Monoliths tractions and counterweight rearmament operations can be coordinated between the teams assigned to the two areas, South and North, of the construction site.
The configuration of the latter doesn't give any role to the King's Chamber.





Two other 3D models of the intercom system, from 2004 on the left and from 2006 on the right.

[319] Discovered by Rudolf Gantenbrink's UPUAUT 2 robot in 1993; the other plate will be discovered by the Pyramid Rover in 2002 (see Page 135).
[320] Name applied during the Arab conquest, several millennia later.

In March 2006, during a stay in Cairo, I personally witnessed an extraordinary event: I was with an American friend[321] in the King's Chamber. At 12:30 p.m., a guard asked us to leave the premises because an American meditation group had rented the King's Chamber for an hour, a regular practice at the time.

We then saw about thirty people arrive, all dressed in white tunics and each carrying a cushion, preceded by a "Master of Ceremonies". They entered the Chamber and started to lie down on the floor. We stayed quietly near the exit, waiting to see what would happen. The "Master" then requested silence and when he got satisfaction, he hit the granite floor by a sharp blow with a tuning fork.

And then we understood what impressive acoustics mean. The sound of the note emitted by the tuning fork resonated in the room, the floor, the walls and the granite ceiling amplifying the phenomenon in an extraordinary way. This phenomenon lasted for quite long seconds. Then the "disciples" began to chant in the chamber, intoxicated by the resonance of the sounds they were emitting.

My friend and I went out of the pyramid, staying in front of it about twenty meters. We were chatting quietly when all of a sudden I said to my friend: "Do you hear? Listen… ".

In the King's Chamber, the "Master" struck the floor with his tuning fork and the notes could be heard very clearly amid the hubbub of the voices of the many tourists present at the foot of the pyramid. The sound was coming out of the North shaft of the King's Chamber; the more we looked at it, the more we heard sounds coming out of it, the disciples resuming their psalmodies more and more, clamors of Giza or calls to prayer from the muezzin being forgotten. Our hearing sense was totally captured by the sounds pouring out of the shaft. Then, all of a sudden, everything stopped and a few minutes later, we saw the "Master" and his thirty or so disciples coming out through the entrance dug by Al-Ma'moun.

Nobody around us had noticed anything as this kind of event could only being experienced by someone very attentive, well impregnated with the pyramid and already alerted by the episode of the arrival of the group in the King's Chamber[322].

For the price of two entrance tickets, we had just lived a very informative scientific experiment on the acoustic qualities of the pyramid's chambers; this one reinforced my idea of a temporary use of the Queen's Chamber and its shafts as a mean of phonic communication.

Finally, to dismiss any objection that could be raised due to the fact that the shafts of the Queen's Chamber did not open[323] into it, it is sufficient to analyze the layout of the blocks of the North and South walls of the Chamber around these shafts and the corridor built in the niche of the East wall.

The northern block, at the corner of the horizontal corridor, has practically no load on it; an inverted corbelling made by the blocks of the upper rows forming a lintel relieves it from the weight of the wall. The latter itself bears no load, the rafter roof not leaning on it. Moreover, its vertical edge has never been dressed, a limestone bead having been preserved to prevent it from being spalled. The three lintel blocks are crossed by a long crack, the only one on the North wall.

---

[321] Jeffrey Kearney, a dialogue writer for several international television channels.

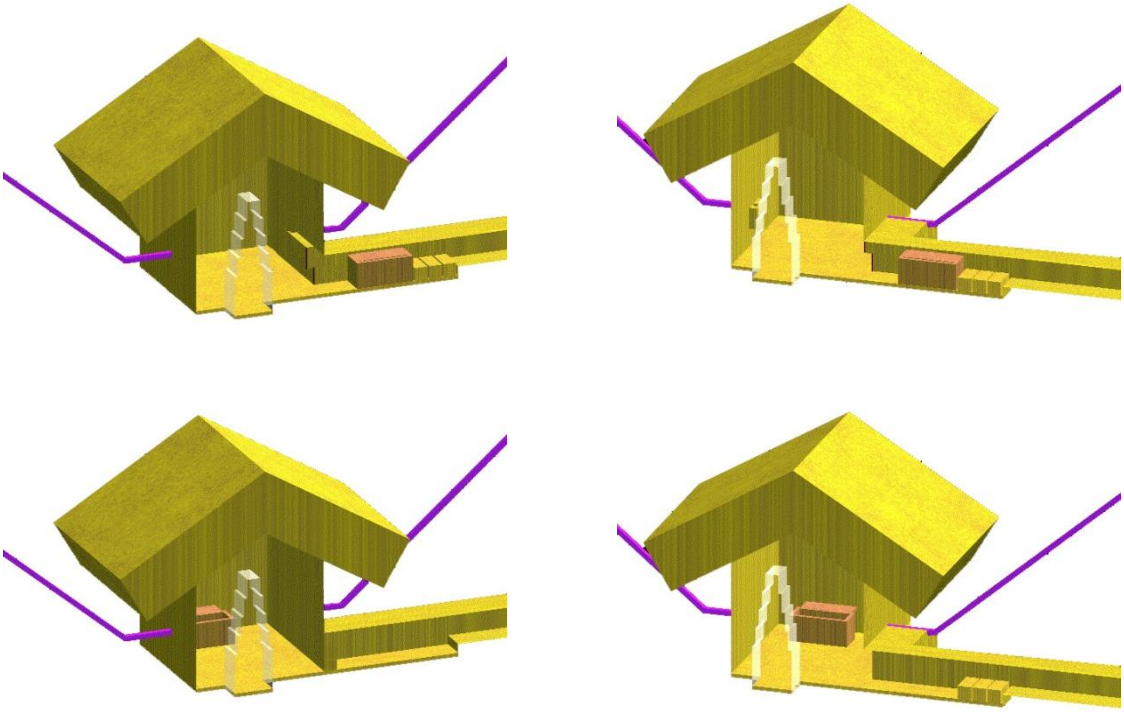
[322] *"In the field of observation, chance only favors prepared minds"* (Louis Pasteur)

[323] The two shafts were discovered in 1872 by Waynman Dixon, an English civil engineer, who had temporarily settled in a tomb dug into the bedrock of the Giza Plateau at the edge of the eastern cemetery; it is in this same tomb that Sir Flinders Petrie will settle in 1880 during his stay at the pyramids. Waynman Dixon will find a ball of dolerite and a copper hook in the North shaft; these two objects are in the British Museum in London.

The southern block is the only one of this wall having no load on it; it is inside a portico made by the matching blocks on either side of it. Strangely, a double vertical crack runs from both the edges of the shaft, crossing three rows of blocks above.

These cracks, plus the one that crosses all the North blocks of the East wall to the right of the niche, are, for me, the consequences of a constraint resulting from the pushing of the drawer-blocks into their housings; the GG1 is on the other side of the horizontal corridor and it was easy to create temporary force for this operation. There was only 30cm to push for each block.

The stones, again, speak very explicitly.



The two blocks, in the North wall and in the South wall, were not drilled, the shafts stopping at 8cm from the interior face of these blocks. In order to let the sound pass, these blocks, like drawers, were pulled of about thirty centimeters in the room for the use of the intercom.
They were then pushed back into their housings to leave no visible trace in the Chamber.
The corridor built in the niche of the East wall was used during these maneuvers.

The interior architecture of the pyramid can now be completed.

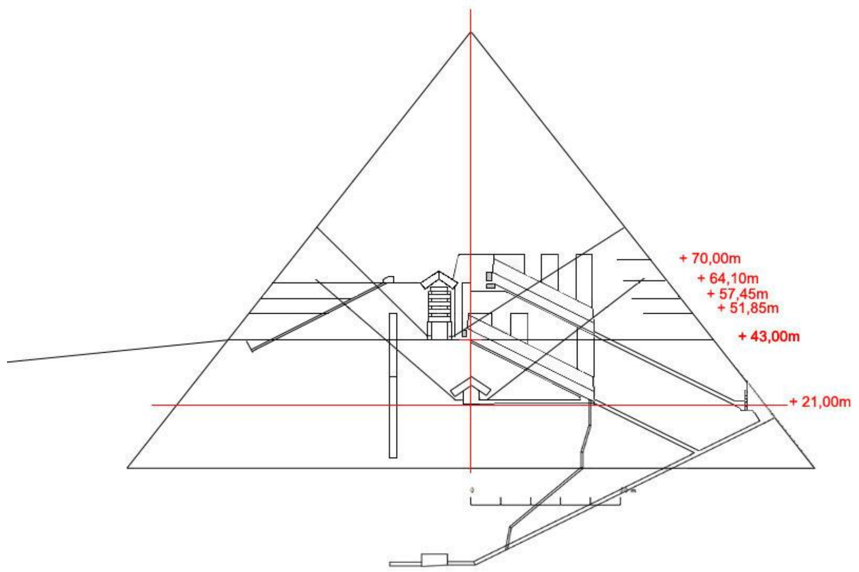
As noted, the GG1 was used extensively in Phases 1B and 2A, with its counterweight making about six hundred and sixty-five round trips, or one thousand three hundred and thirty trips in the latter, with one important consequence: the cedar rollers in the roller train were wearing out and had to be replaced frequently with new ones. The need for nearby spares led the designers to create a horizontal corridor from the bottom of the GG1 to the Queen's Chamber; much of this had alcoves facing each other, bringing the available width to four cubits, identical to that of the GG1.

Nearly four hundred logs[324] could be stored in a constant humidity and temperature. At the end of the GG1 use, the alcoves were filled in with limestone slabs, erasing their existence.

The shafts for the Queen's Chamber and the King's Chamber completed the plans, with an additional feature for the latter: to ensure the ventilation of the King's Chamber once its construction was completed. This Chamber was the first to be built at a level much higher than the entrance to a pyramid. Up to this point, the pyramid was naturally ventilated by the corridors, the GG1 and the GG2 and their wide-open modulation wells. Once all the structures were buried in the mass of stone, all that remained were the King's Chamber shafts that led to the outside.

Talking one day with Jean Kérisel, who had worked in the 90's on the renovation of the ventilation of the Chamber, he told me of his astonishment when, the day the shafts were unblocked, fresh air literally rushed into the room. This did not surprise me because of the positioning of these shafts, on a North-South axis: an exit in the North, a colder face because less exposed to the sun and another, in the South, a warmer face because in full sun. This arrangement naturally produced a suction effect; the hot air licking the South face sucked in, through the South shaft, the cooler air from the North face through the North shaft. On its way, it crossed the room, ensuring good ventilation.

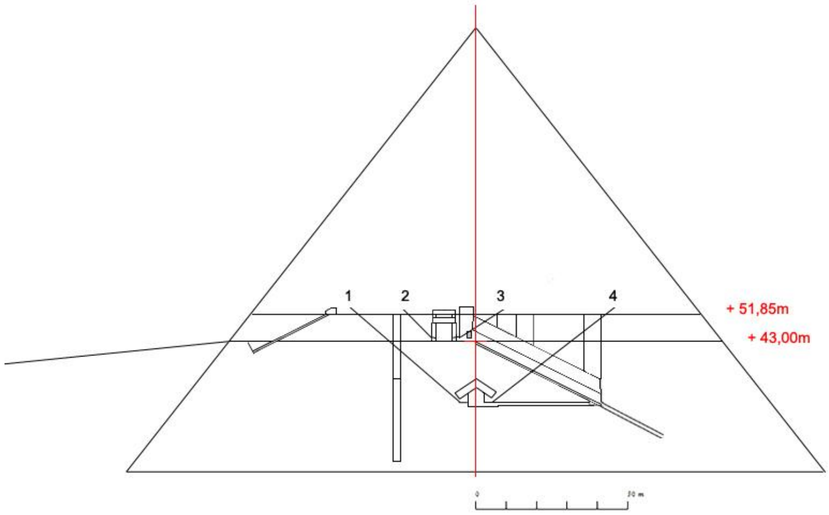
Only the last structures[325] remained to be created: the descending corridor leading from the entrance on the North side to the Subterranean Chamber and the extension of the two ascending corridors connecting the GG1 and the GG2 to the descending corridor; finally a service well was decided to ventilate the Subterranean Chamber during the excavation works.

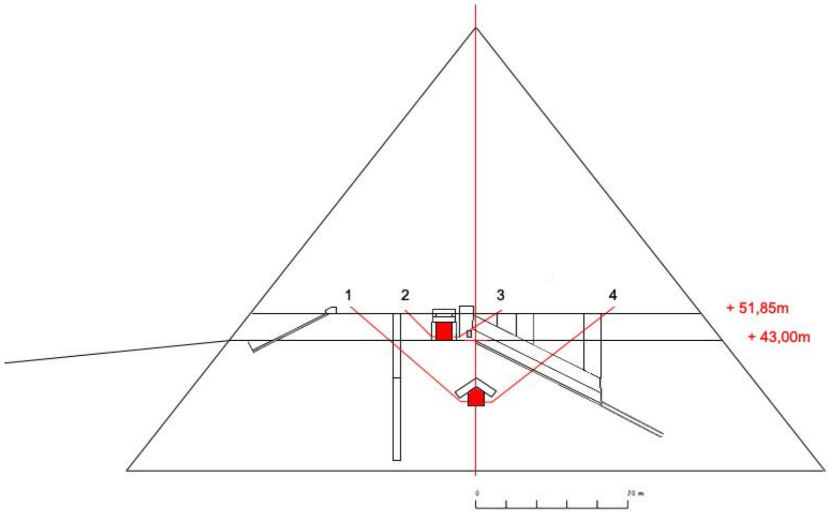


Cross-section of Khufu’s pyramid compiling all the structures that participated in the construction of the King's Chamber and its superstructure, the unknown structures being integrated: the load modulation wells of the counterweight above the GG1, the GG2 and its modulation wells, the motor well of the GG2, the motor well of the GG1 and the ramp-slide for the hoisting of the monoliths of the superstructure
The ScanPyramids mission discovered the GG2 and its load modulation wells.
A careful eye should quickly understand the extraordinary geometry of the shafts of the Queen's Chamber and the King's Chamber and their interaction with the ceilings and roof levels of the latter.

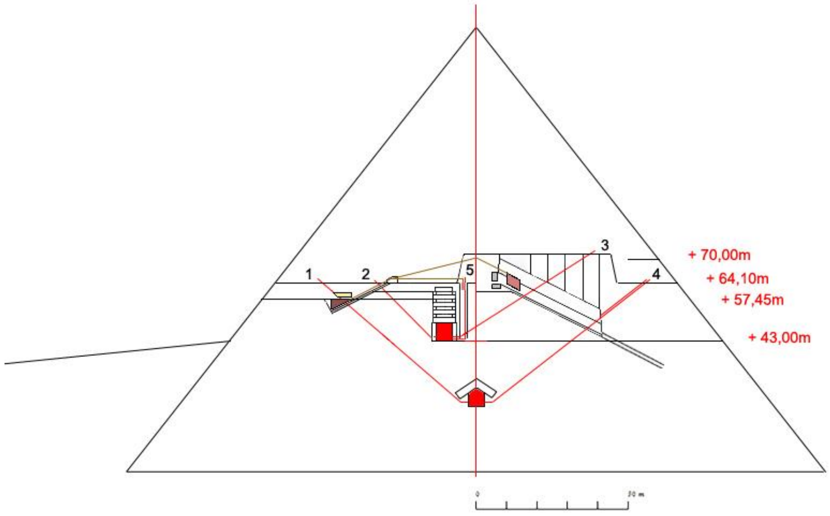
324 This prevented access to the Queen's Chamber for several years. This was not the role of this corridor, access being provided by another circuit.
325 In this paragraph, I refer only to the other known structures of the pyramid. For those that I imagine in my theories, the Noble Circuit and the inner ramp, I will discuss them in the documents to follow.

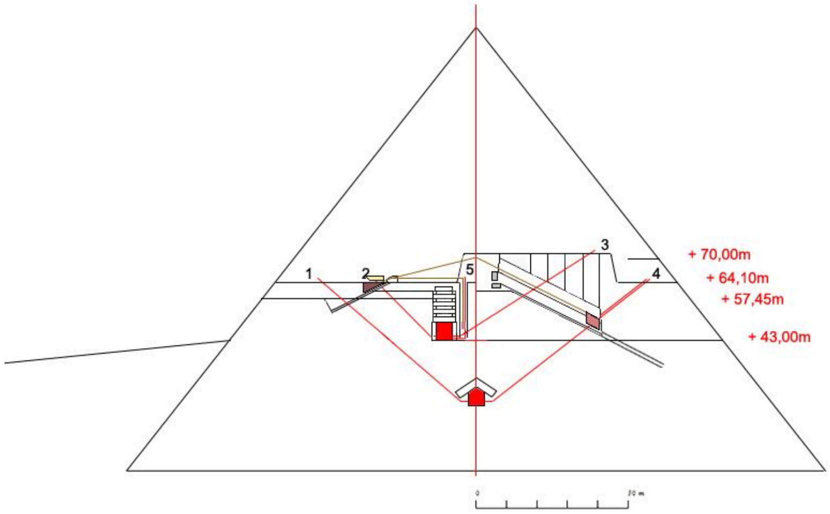
Diagrams showing the extraordinary geometry of the shafts of the two chambers.





Example of the relationship between the Chambers and their shafts with the structures involved in the counterweight system, in this case, during Phase 2A of the construction of the King's Chamber with the GG1.
During the construction of ceilings 1 and 2, the Queen's Chamber shafts provide direct communication between the top of the monolith hoisting ramp-slide (1) and the lower well of the GG1 (4). The King's Chamber shafts provide communication between the motor well (2) and the upper well of the GG1.
The short distance between (1) and (2) allows the exchange between the two sound networks.
The order transmission stations each have their own role:
The station (1) transmits the information concerning the loading of a monolith on the hoisting platform before a traction; ditto during the loading of the blocks on this same platform for the rearmament of the counterweight
The station (2) transmits the information concerning the motor
The station (3) transmits the information of the counterweight in the upper position during the laying of the overloads through the two upper wells according to the ceiling under construction.
Station (4) transmits the information about the removal of the overloads before any new rearmament.
Audio operators are placed at each station and inside the Chambers, with one operator positioned at each opening into the chambers. These operators "relay" the orders they receive, helped by the exceptional acoustics of the Chambers.
All operational orders related to the counterweight system are thus transmitted in real time.
Add to this those linked to the monitoring of all moving parts: counterweight trolley, hoisting platform and rollers-trains, plus the condition of the ropes in operation.





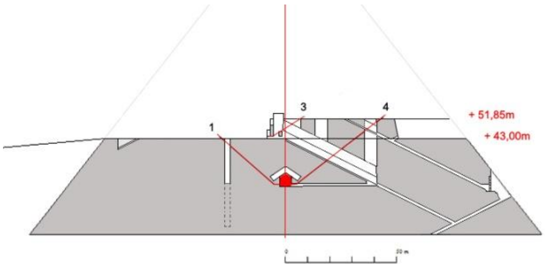
Example of the relationship between the Chambers and their shafts with the structures involved in the counterweight system: In this case, the hoisting of the limestone roof beams during Phase 2B2 with the GG2.

The station (1) transmits information about the loading of a beam on the hoisting platform.
The station (2) transmits the information concerning the unloading of this beam and the loading of the blocks on this same platform for the rearmament of the counterweight.
Station (3) transmits the information about the removal of the overloads before any new reset.
The station (4) is doubled, a shaft parallel to the North shaft of the Queen's Chamber, starting from the North wall of the GG2, joins it at the level +64.10m. An operator is stationed in a niche built into this North wall, monitoring the movements of the counterweight. From the double post (4), any information can be transmitted in real time to the network.
In addition to the shafts, an additional transmission circuit connects the station (5) at the top of the motor well directly to the King's Chamber. Through this circuit, near the GG2, an operator manages the information of the counterweight in high position during the laying of the overloads through the two upper wells. Standing in the Portcullis Chamber, between the fixed portcullis and the North wall[326], a second operator relays the information to the operators in the King's Chamber

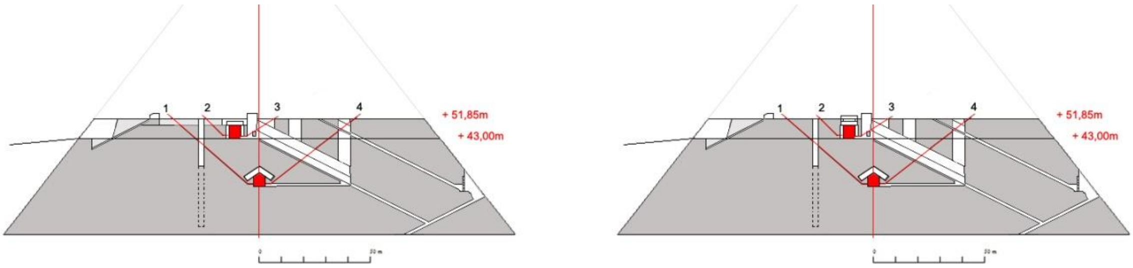
The relationship between the Chambers and their shafts with the structures involved in the counterweight system is identical in Phase 2B1 with the GG2.

[326] See footnote 183 on page 31.

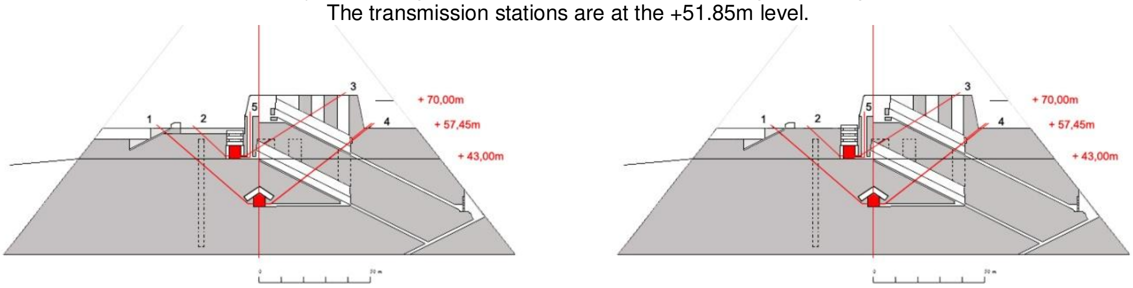
Illustration, from the 2011 version of my work, showing an operator transmitting information through the South shaft of the Queen's Chamber. The proximity of this shaft to the axis of the GG1 was imperative.



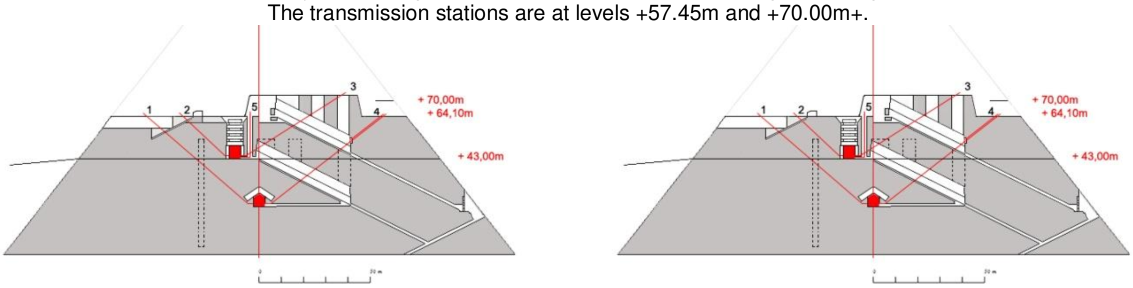
The intercom system during Phase 1B.
The transmission stations are at levels +43.00m and +51.85m.



The intercom system during Phase 2A, on the left the 1st ceiling, on the right the 2nd .
The transmission stations are at the +51.85m level.



The intercom system during Phase 2B1, on the left the 3rd ceiling, on the right the 4th.
The transmission stations are at levels +57.45m and +70.00m+.



The intercom system during Phase 2B2, on the left the 5th ceiling, on the right the roof.
The transmission stations are at levels +64.10m and +70.00m+.

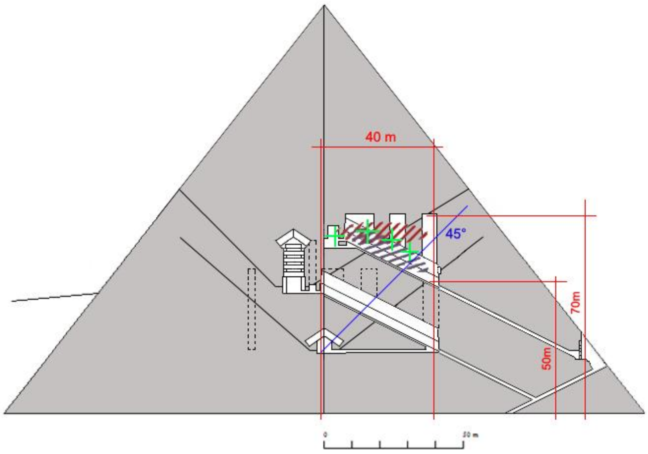
9 - THE BIG VOID IS THE CENTERPIECE FOR THE SUPERSTRUCTURE CONSTRUCTION ABOVE THE KING'S CHAMBER

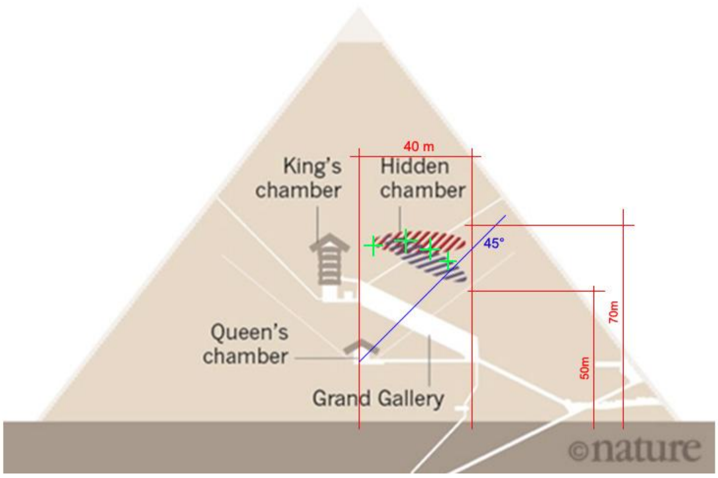
"Everything possible to be believed is an image of the truth".
William Blake[327] .

After more than 80 pages of presentation, explanations and demonstrations, I feel totally confident about the comparison of the GG2 to the BIG VOID discovered by the ScanPyramids mission.

First, I quickly return to the article published in the journal *Nature* on November 2, 2017 and the accompanying illustration. Then I return at greater length to the document "2019 Scientific Report - September 2019"[328], particularly to the analysis of the data acquired from the Grand Gallery by the Nagoya team: a series of images representing the muons collected by the plates and a diagram with the limits of the BIG VOID.

The architecture seen in vertical plane of the GG2 being perfectly defined, a last comparison with the illustration of *Nature* completed with the updated dimensional characteristics is already very telling.



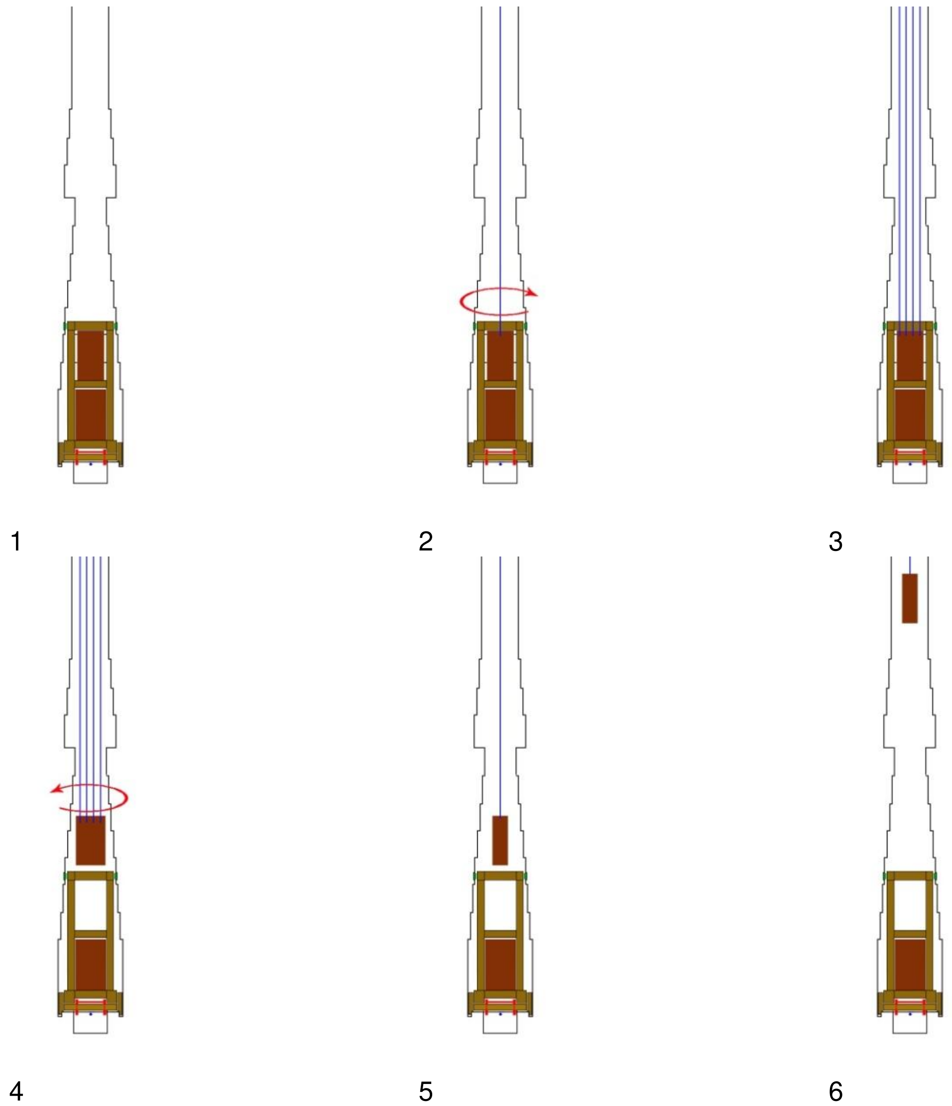


In addition to the epicenter crosses (in green) and the hatched blue and red zones, the latest announced dimensions are applied on the latest version of the GG2 and on the *Nature* illustration; the correspondence is perfect.
The GG2 is totally within the length of "more than 40m" and the height "between +50m and +70m" of the base.
As a reminder, the epicenter zones and crosses were defined from the results of the emulsion plates installed in the Queen's Chamber; those in the Grand Gallery were installed later.

[327] William Blake (1757-1827). *The Marriage of Heaven and Hell: In Full Color.*
[328] Pages 46, 47 and 48 of the document.

Since the architectural cross-section of the modulation wells has an impact on the imprint left by the muons on the emulsion plates, it is useful to provide some additional information regarding their shape and function.

Cross-sectional schematic applicable to the GG1 and the GG2.
Extraction of an overload block from the lower well.

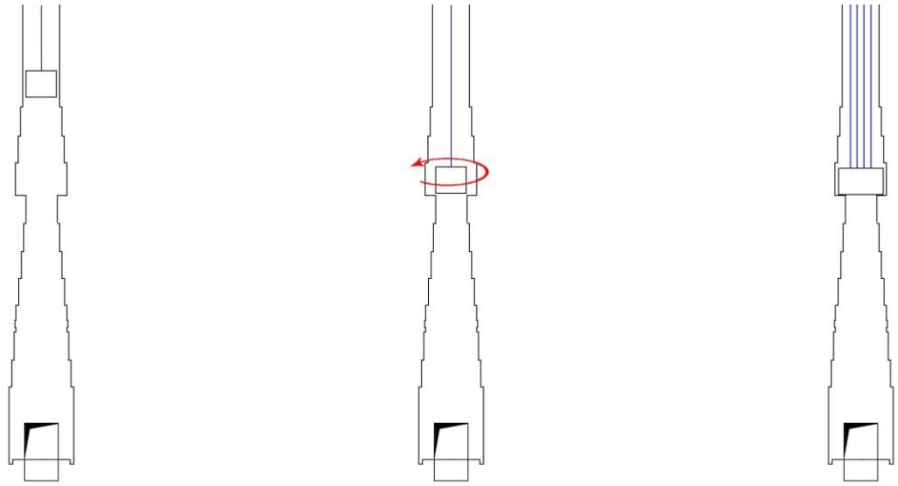


The load of the basic counterweight is on the lower level, the overloads are placed on the upper level (1). Before the counterweight rearmament, the overload blocks are removed one by one through the lower well. As the blocks measure 1.02m x 0.52m x 1.57m, the rotation[329] of the blocks is necessary if they are laid transversally, one behind the other (2), (3) and (4). The 180° return technique is used, a reduced team[330] hoists the blocks while being positioned perpendicularly to the opening of the well, the ropes bringing up the block longitudinally (5) in the well of approximately 1,20m wide. The well is widened[331] at its base in order to allow the installation of the cover slabs[332] of the galleries[333] .

This sequence is reversed for the addition of overloads through the intermediate and upper wells of both galleries.

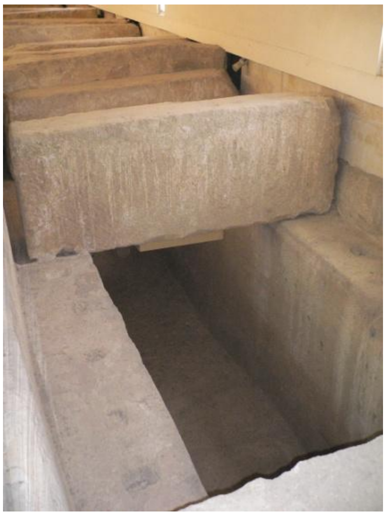
[329] Unless the blocks are laid lengthwise in pairs. The overall footprint is the same on the trolley.
[330] A dozen men in total.
[331] A solution already realized in the well adjacent to the antechamber of the Bent Pyramid at Dahshur.
[332] And possibly to allow a person to control the entry of the block in the well during extraction or in the gallery during the laying on the trolley.
[333] See next page.

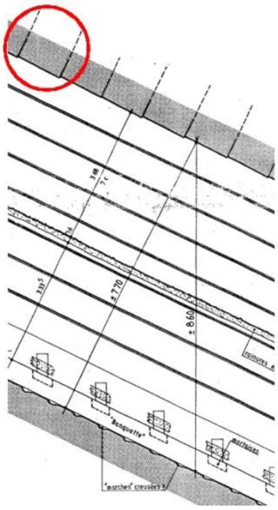
Cross-sectional schematic applicable to the GG1 and the GG2.
Installation of the covering slabs of the galleries.

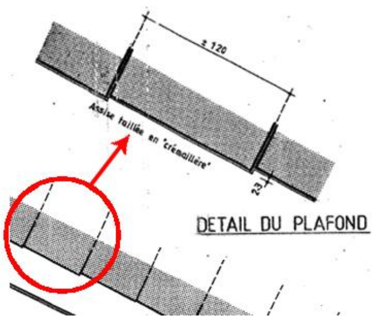


1 2 3

Setting of the cover slabs at the end of the counterweight use.
The slabs are lowered longitudinally through the wells (1).
Near the level of the lateral supports, the slabs are rotated by 90° (2).
They are then placed on their supports (3).
The wells of the GG1 are backfilled with small blocks and cuttings of local limestone, as is the case for the mastabas, in order to reinforce the structure under the GG2.
The wells of the GG2 were not backfilled[334], the setting of limestone beams[335] at their outlet being sufficient.





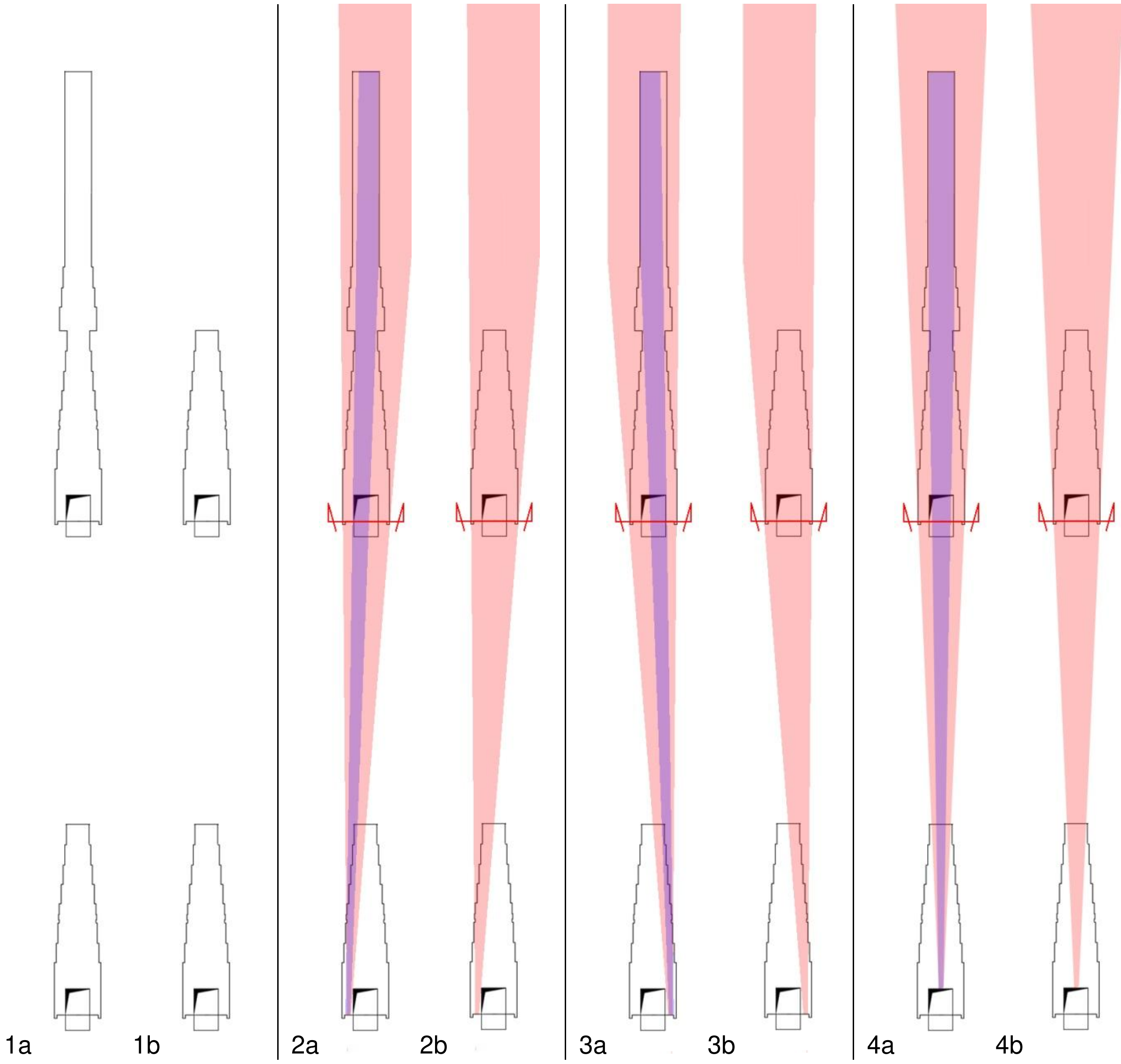


Gilles Dormion drawings

The wells above the GG1 and the GG2 were covered with limestone slabs using the same technique as that used to cover the boat pits at the foot of the pyramid.
Because the span is smaller, the beams are smaller and less high.
The supports in the upper part of the galleries were cut with redents in order to prevent the transfer of loads from a beam to the lower beam, these loads being transferred directly onto the redents.
This technique was implemented because it allows uncovered sections to be retained and their coverage to be deferred to a later date without risk to the structure.

334 The results of the ScanPyramids mission indicate large voids in these areas.
335 According to the technique of covering the boat pits at the foot of the pyramid.

Schematic cross-sections of the GG1 and the GG2 positions with and without wells.
Trajectory of the muons crossing the GG2 according to the positions of the plates in the GG1.

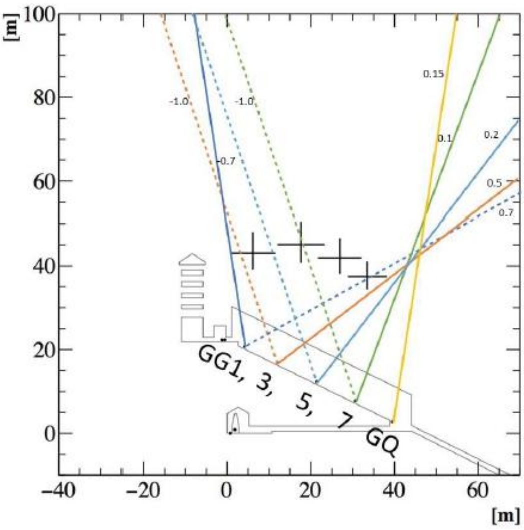


Each pair of diagrams represents, on the left, (subscript a), a cross-section of the GG1 and the GG2 at the lower well above the GG2, and on the right (subscript b), a cross-section outside a well above the GG2.
Since the wells above the GG1 are filled in, no wells are shown (1a, 1b and following).
In (2a and b), (3a and b) and (4a and b), in pink, the cone of muons passing through the GG2 and, in blue, the cone of muons passing through the well and the GG2 before reaching the emulsion plates positioned in the GG1.
The muons trajectories are "omnidirectional", which means that the emulsion plates record them in a square-based receiving beam at an angle of about 90°[336] .
The trajectories of these cross sections combined with the trajectories of the longitudinal sections[337] give an idea of the overall "radiating" trajectories.
Last point, before passing through a cavity, the length of the muons path in the mass influences the number of muons that can be recorded by the emulsion plates. On the one hand, although the amount of vertical muons is greater than at a 45° angle, the absorption is greater in the center of the pyramid because of the thickness of the limestone above the GG2; on the other hand, the distance from the GG2 perpendicular to the North face being shorter, the lower amount of muons is compensated by a lower absorption[338] .
Emulsion plates record muons accumulated at the red cut line at the bottom of the GG2.
Between the start of the ScanPyramids mission in October 2015 and the latest results announced in September 2019, the Nagoya University team more than doubled the exposure time of the emulsion plates from 40 days to more than 90 days; this technological achievement significantly improved the amount of muons received at all angles.

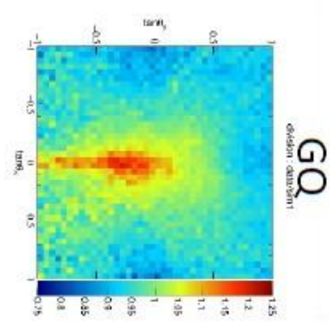
336 See 3rd paragraph Page 28.
337 This will be discussed in the following pages.
338 See 6th paragraph Page 28.

Now, a detailed analysis of the results announced in the document "2019 Scientific Report - September 2019" brings many clarifications supporting my interpretation of the BIG VOID as the GG2; this second Grand Gallery is essential for the construction of the structure above the King's Chamber.

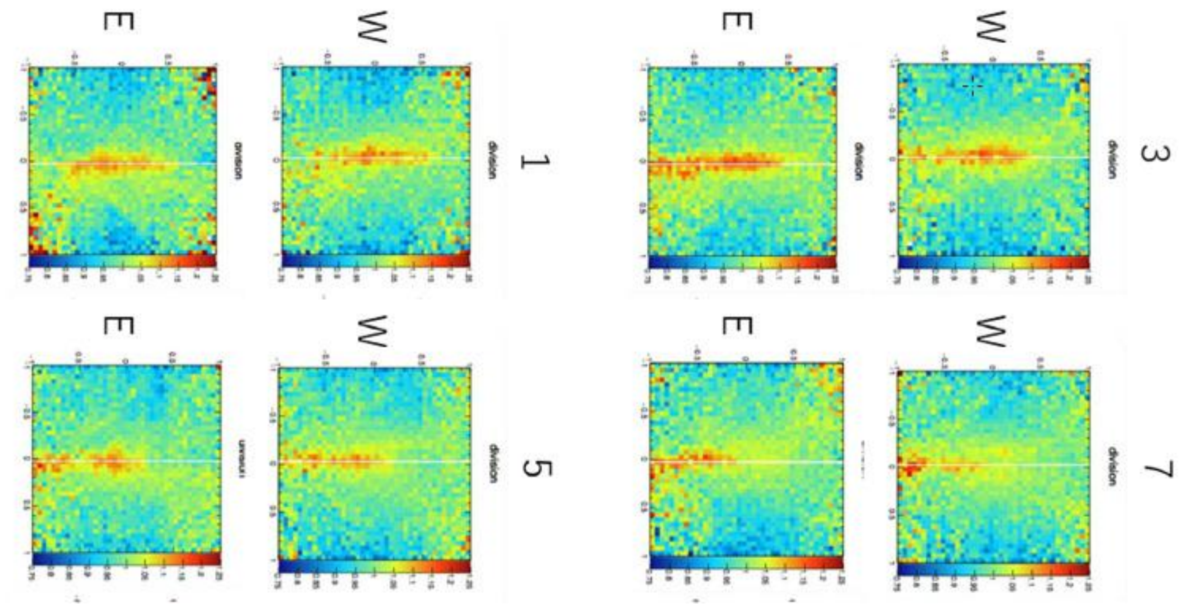
Back to the diagram and images[339] published in the September 2019 paper. In the following pages, the position of the epicenter crosses and the data recorded by each pair of plates will be compared with the GG2 architecture.



North-South sectional diagram summarizing the results. The solid colored slanted lines indicate probable limits of the BIG VOID.



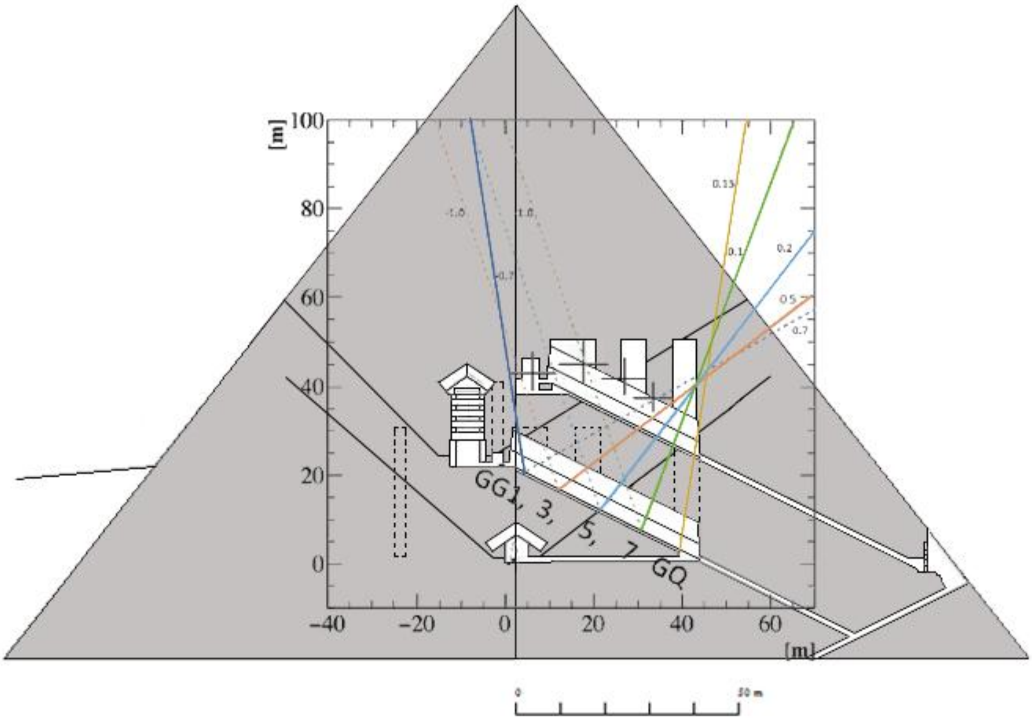
At the bottom of the Grand Gallery, there was only one central position (GQ).



Each pair of images is composed of a position of plates on the East side (E) and one on the West side (W), these being laid on the side benches of the Grand Gallery.
The number on the right indicates the position of these plates in the Grand Gallery as shown in the diagram (GG1, GG3, GG5 and GG7).
For a better reading of the data, the images were rotated 90° to match the position of the plates shown on the North-South cross-section diagram with the image of the GG2 in the North-South cross-section of the pyramid.

339 Already shown Page 46.

Data recorded by the Nagoya team during the ScanPyramids mission between 2016 and 2019.
Application of the diagram published in September 2019 on Khufu's Pyramid featuring the GG2.



North-South section of Khufu's Pyramid with, in superimposition, the diagram summarizing the results of the Nagoya University team acquired during the ScanPyramids mission.

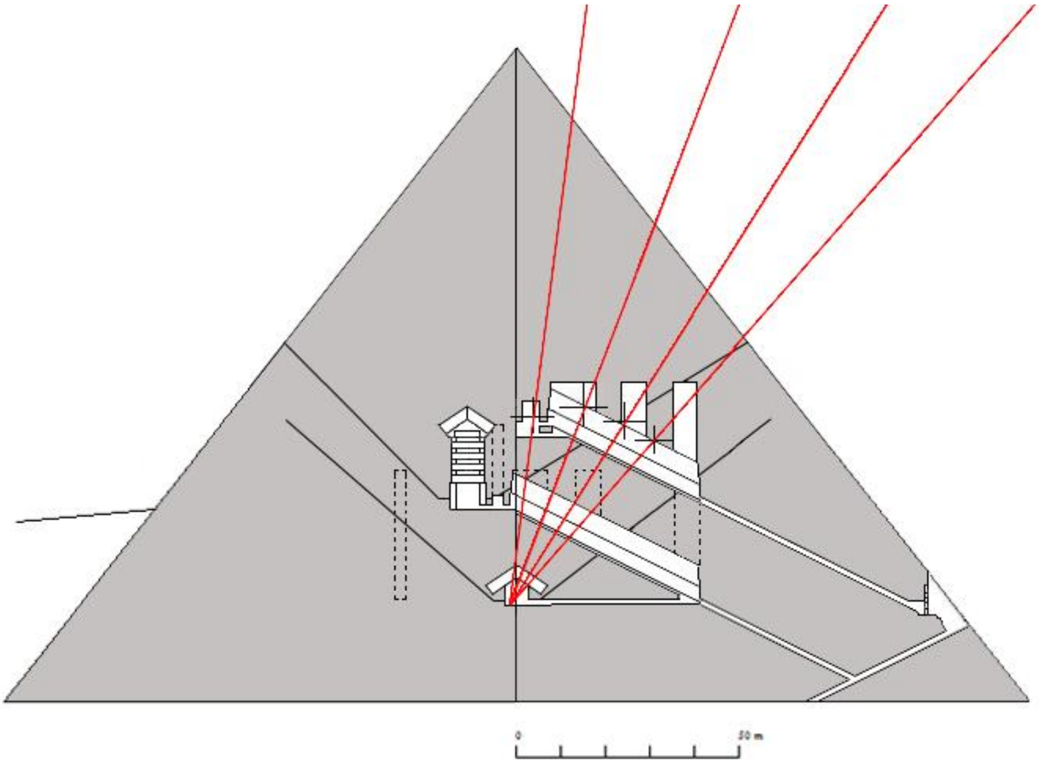
This document is analyzed in detail in the following pages.

Analysis of the position of the crosses[340] materializing the epicenters of the voids detected by muography that were published in the November 2, 2017 *Nature* paper.

As I wrote in the 5th paragraph on Page 28:

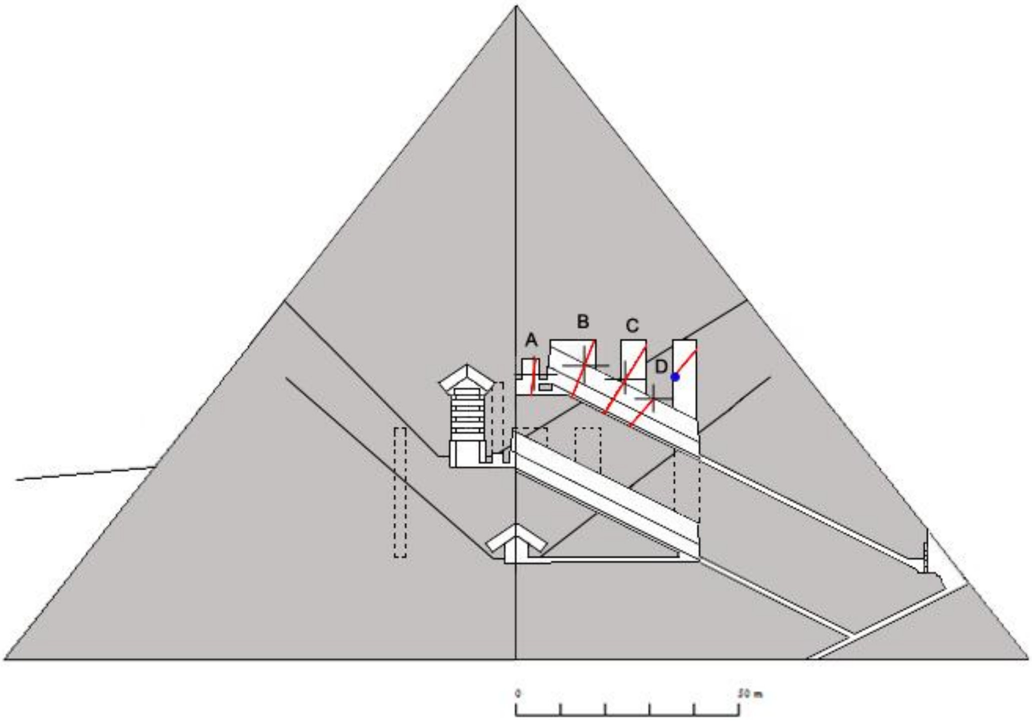
-The third one, that the detectors could not segregate between one or several crossed voids and that the epicenter of a trajectory in a void only indicated an equal length of void on both sides of it but not necessarily in the same void.

This rule becomes important in the analysis below.



Data recorded by the emulsion plates installed in the Queen's Chamber.
The red lines represent the muons trajectories with the recorded detection peaks.
The position of these peaks, or epicenters, is materialized by the crosses.

[340] Epicenters A, B, C and D - see Footnotes on Page 36.



For a better understanding, I have added the original letters distinguishing the peaks.

Peaks A, B and C are all at the epicenter of the same void:

- A is outside of the GG2, in an adjoining room (like the Portcullis Chamber next to the GG1),

- B is at the epicenter in a void made of the GG2 and its upper well,

- C is at the epicenter in a void made of the GG2 and its intermediate well,

- D is at the level of the roof of the GG2, at the epicenter of two successive voids made of the lower well and the GG2.

What is remarkable in this case is that this peak D had, at first[341], been positioned in the first void, at the southern limit of the well (see blue dot in overprint). This position had not been confirmed because of insufficient sigma. Following the increase in the amount of data received by the plates in the following months, point D, confirmed at +5sigma[342] was finally placed in its final position, "jumping" from the limit of the first void to that of the second, the GG2.

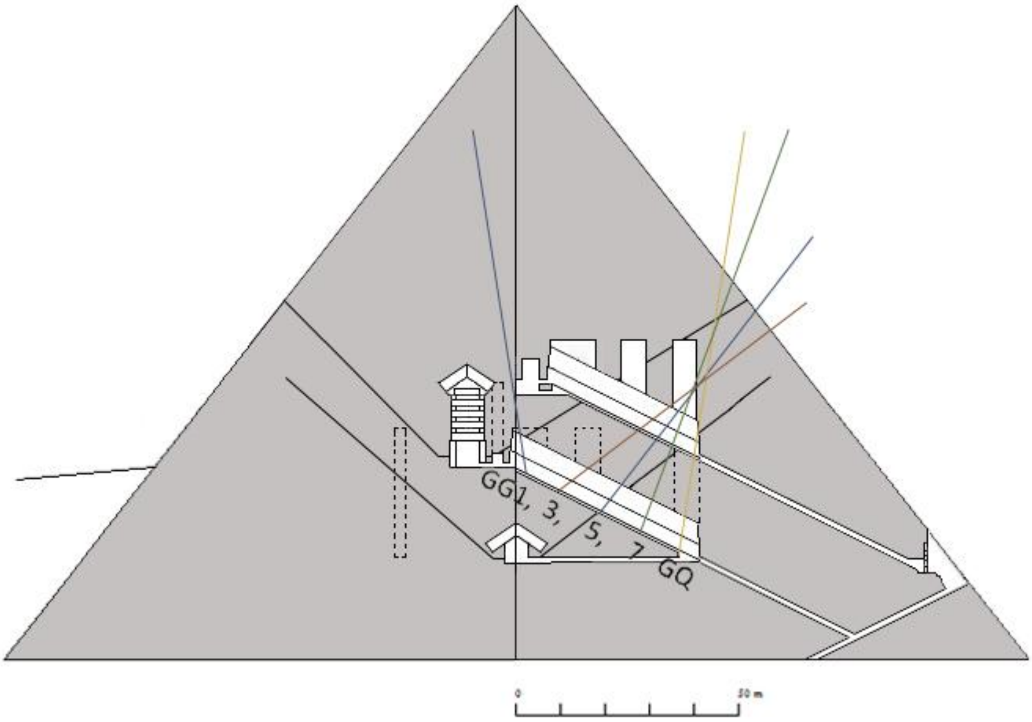
The three trajectories in the GG2 and the one in the annex room are the longest possible in these voids, contiguous or successive, from the plates placed in the Queen's Chamber and the three epicenters B, C and D are on the same slope parallel to the GG2 at its roof level.

Remark:

The emulsion plate technique used by the Nagoya team is outstanding; the precision of the data recorded from the plates laid in the Queen's Chamber already provided very valuable information.

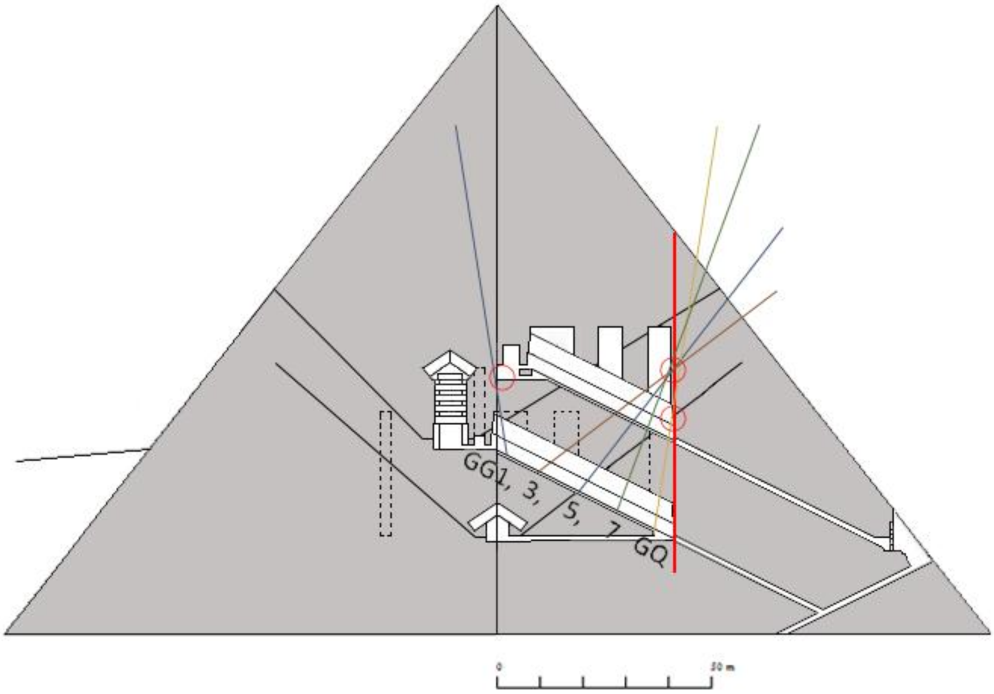
[341] See Page 25.
[342] See page 36.

Analysis of the presumed limitations of the BIG VOID materialized in the September 2019 diagram.



For better readability, the continuous lines reproduced are taken from the diagram on Page 84.

- On the left, the dark blue line marks the southern limit determined by the plates laid in the GG1, almost vertically.
- In the center, the brown, light blue and green lines determined by the plates laid in GG3, GG5 and GG7 all cross at the same point indicating the northern limit.
- To the right, the beige line determined by the plates placed in GQ marks a second northern limit, on the same vertical as the point above.

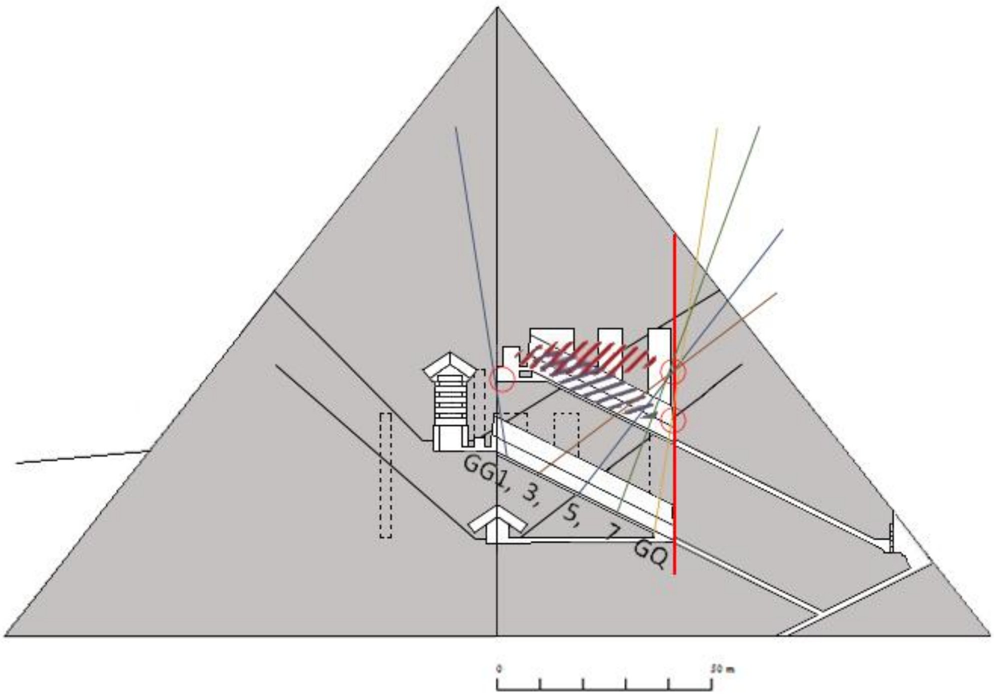


- Red circle on the left: the southern limit is on the East-West axis of the pyramid, at the level of the floor of the access corridor to the GG2 in the adjoining annex (like the Portcullis Chamber and Grand Gallery).

- Upper red circle on the right: the northern limit is the northern wall of the lower counterweight load modulation well of the GG2, limit confirmed from the three plate positions in GG3, GG5 and GG7.

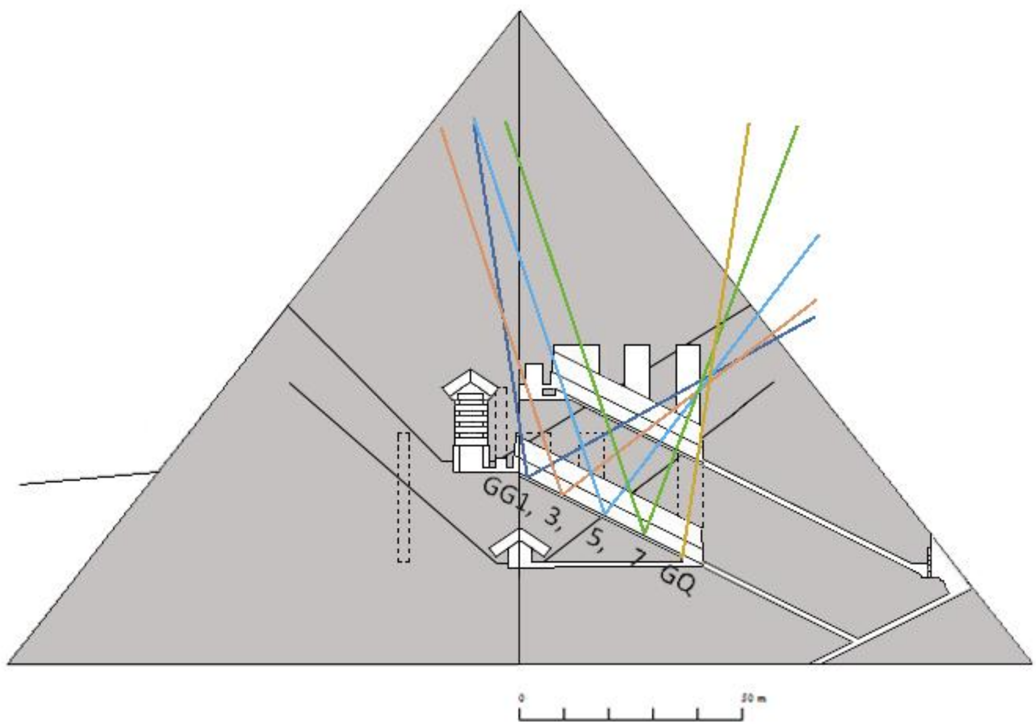
- Lower right red circle: the northern limit is the northern wall of the GG2.

The two northern limits on the right are on the vertical alignment line of the North walls of the Grand Gallery and the GG2.



The indecision as to whether or not the BIG VOID is inclined is understandable without a very thorough architectural analysis. The position of the upper red circle on the North side can be misleading and it takes a great deal of knowledge of Khufu's Pyramid and its construction processes to get an understanding that is difficult to refute.

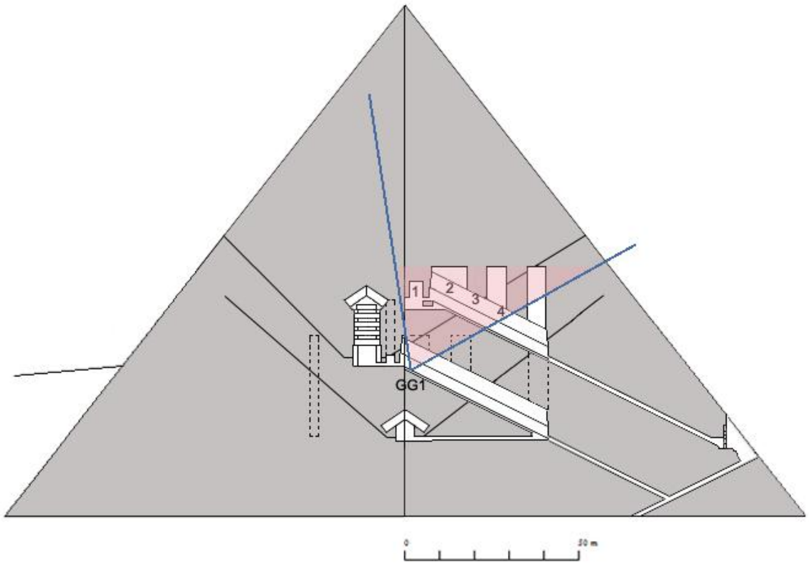
In-depth analysis of the data recorded by the emulsion plates laid in the Grand Gallery, as reproduced in the diagram published in September 2019.



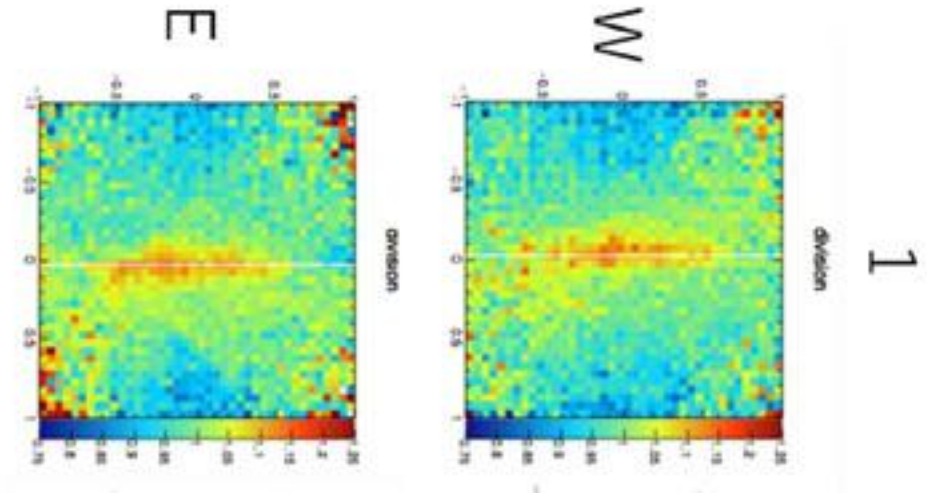
The muons detection cones are extracted from the diagram.
Each cone is now compared to the corresponding emulsion plates[343] .

343 Although I have received a lot of information from muons specialists for more than 10 years now, these comparisons and my explanations are only based on my understanding of the "muons shelling" that our planet is undergoing.
That said, these explanations are based on :
- A simple and logical reasoning resulting from a careful study of the supposed architecture,
- The images of the emulsion plates published in "2019 Scientific Report - September 2019".

Analysis of the East and West plates laid in GG1.



In dark blue, the detection cone of the plates placed in the Grand Gallery in GG1.



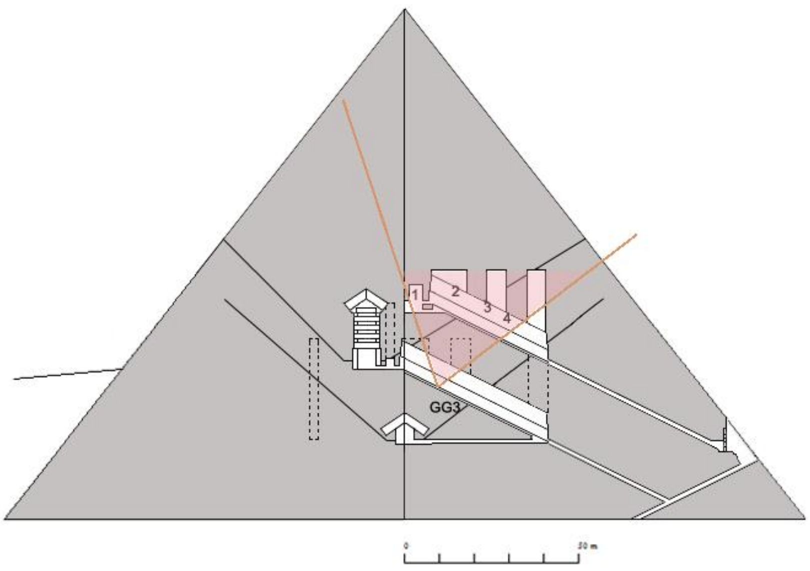
Comparison of the BIG VOID-GG2 with the East, left, and West plates, right.
The muons accumulations can be different from one plate to another, the announced results are based on the accumulation of the plates on both sides.

GG1 position is very central and penalizes the detections in (1).
The annex room (1) being smaller and directly under the summit and 70m of limestone, receives less muons.
On the other hand, the distance to the outside, the North face, is shorter for (2), (3) and (4).
The areas with the upper well (2) and the intermediate well (3) are denser because they receive more muons.
The lower part of the cone is low but detects the upper part of the lower well (4).

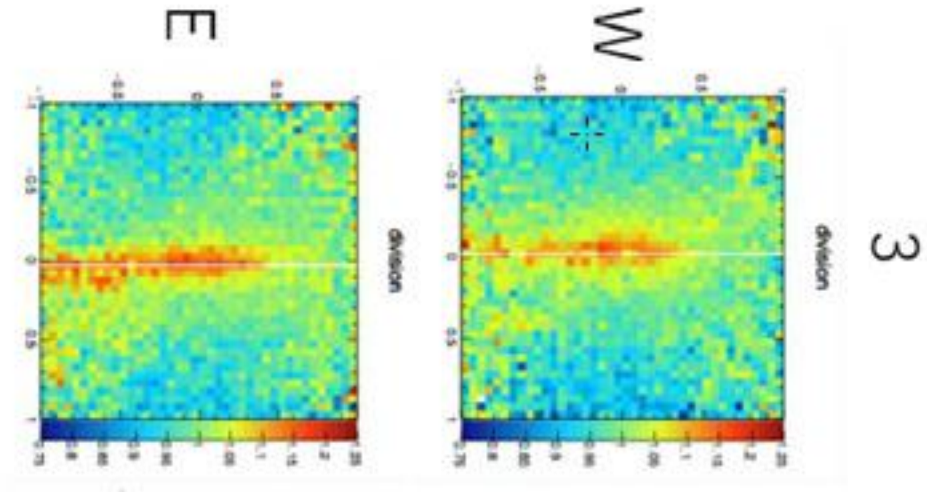
The footprint left on the plates reflects the oblique trajectories; the footprint of the wells is shifted and more pronounced than that of the GG2 alone[344] , on the East and West sides, on either side of the plate axis (white line).

[344] As shown in blue in 2a and 2b in the diagrams on page 85.

Analysis of the East and West plates laid in GG3.



In brown, the detection cone of the plates laid in the Grand Gallery in GG3.

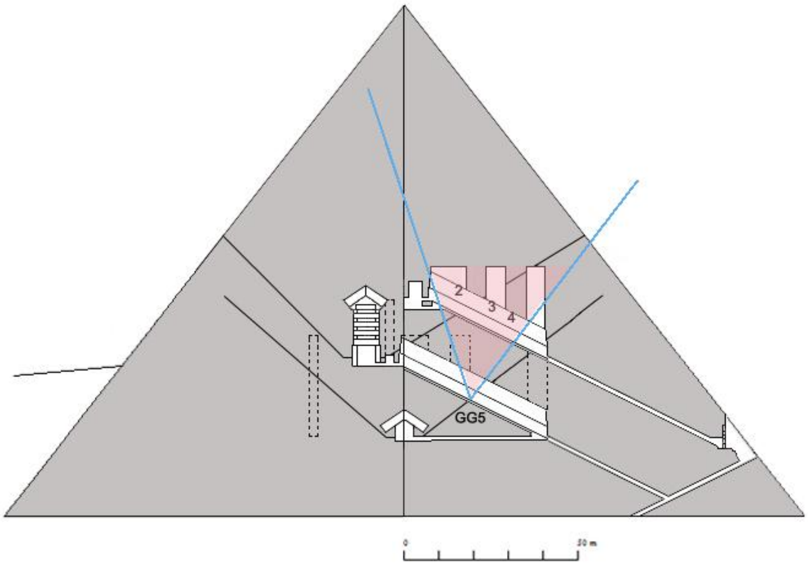


Comparison of the BIG VOID-GG2 with the East, left, and West plates, right,
The muons accumulations can be different from one plate to another, the announced results are based on the accumulation of the plates on both sides.

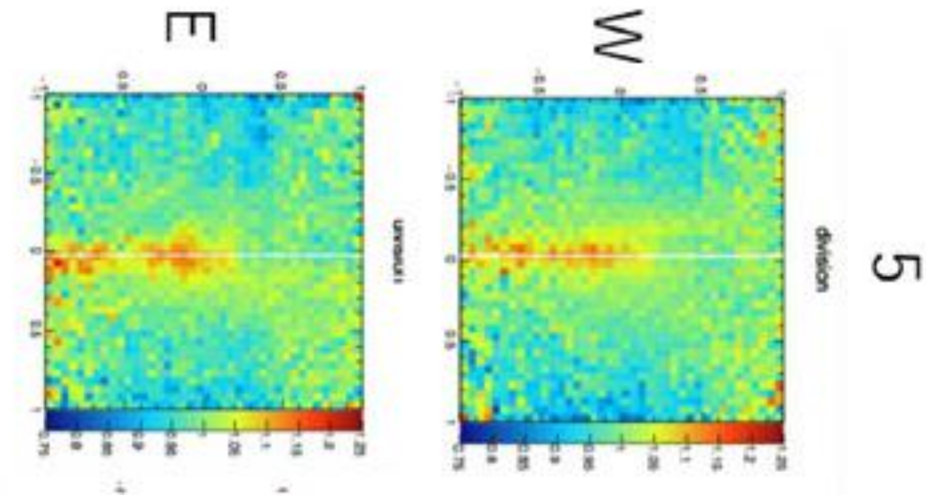
The adjoining room (1) is better detected, receiving more muons from the closer South face, while the concentration in the upper well area (2) is impacted by GG3 position which places it directly below the summit.
The concentration is highest in the areas of the intermediate well (3) and a large part of the lower well (4), the distance to the outside, the North face, being always shorter for (3) and (4).
The footprint left on the plates reflects the oblique trajectories; the footprint of the wells is shifted and more pronounced than that of the GG2 alone[345] , on the East and West sides, on either side of the plate axis (white line).

[345] As shown in blue in 2a and 2b in the diagrams on page 85.

Analysis of the East and West plates laid in GG5.



In light blue, the detection cone of the plates laid in the Grand Gallery in GG5.

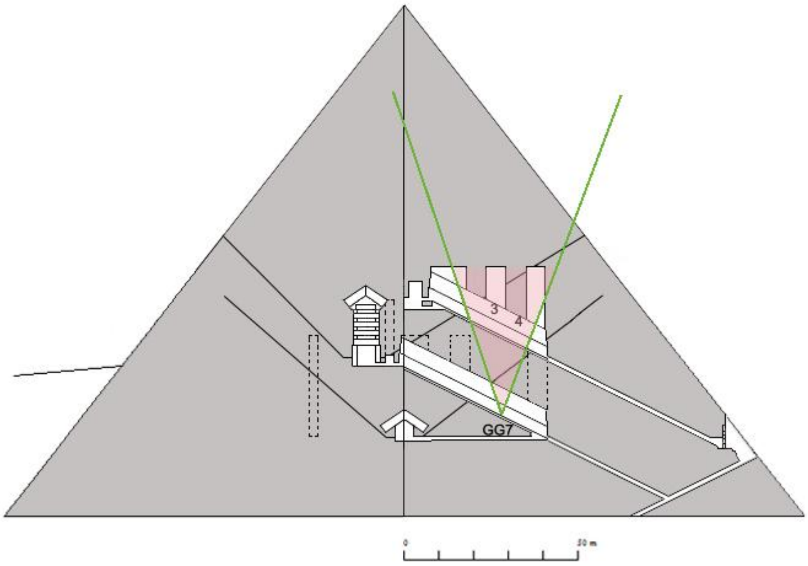


Comparison of the BIG VOID/GG2 with the East, left, and West plates, right,
The muons accumulations can be different from one plate to another, the announced results are based on the accumulation of the plates on both sides.

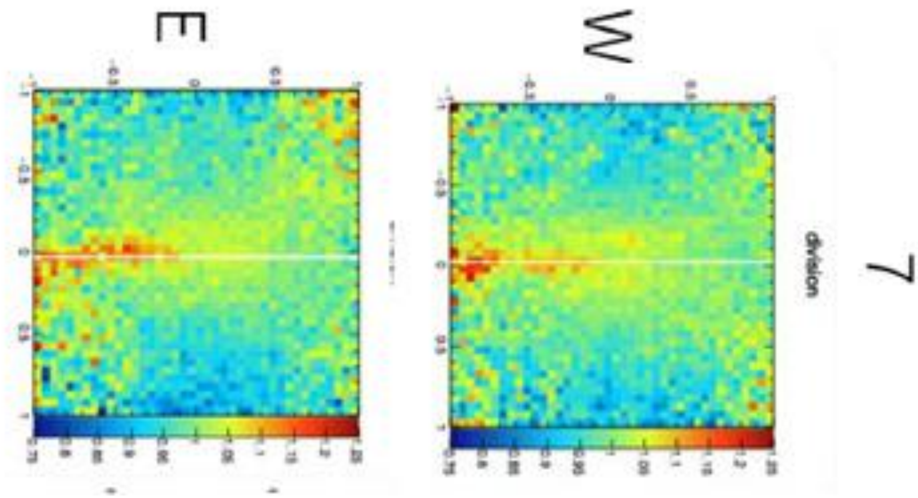
The annex room is outside the cone from position GG5, which descends into the Grand Gallery.
This cone, while moving away, by rotation, from the North face, causes a decrease in the concentration of muons in the zones of the upper well[346] (2), the intermediate well (3) and the lower well (4).
The footprint left on the plates is smaller because the mass height above wells (2) and (3) is greater.
As the muons were more absorbed before crossing the GG2, the eastern and western sides are less detected.
The solid area between (2) and (3), vertically to GG5, absorbs more muons.

[346] Which still receives muons from the South face.

Analysis of the East and West plates laid in GG7.



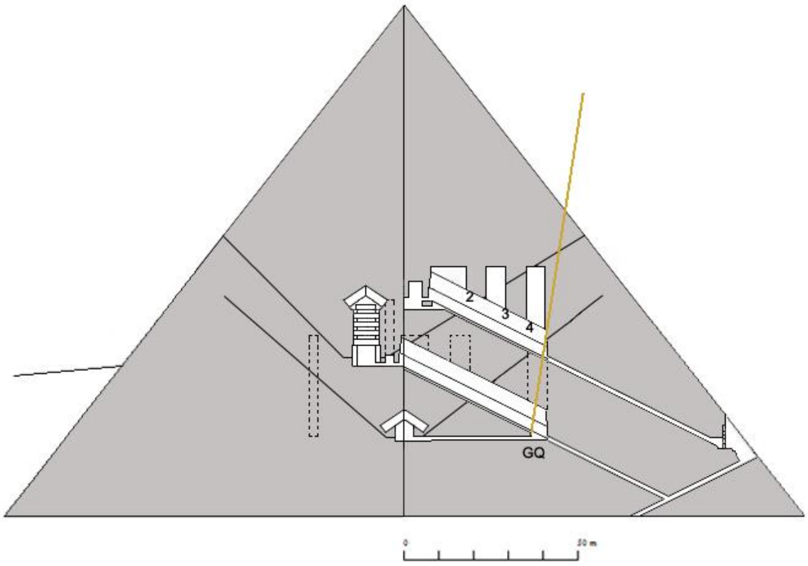
In green, the detection cone of the plates laid in the Grand Gallery in GG7.



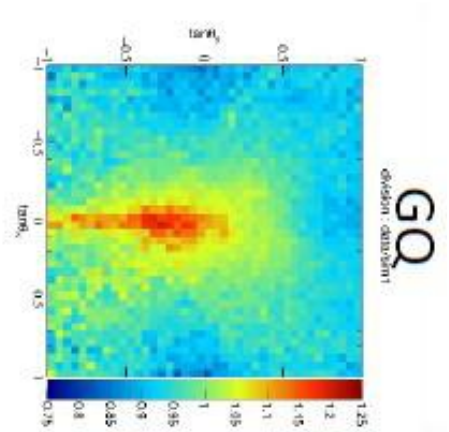
Comparison of the BIG VOID/GG2 with the East, left, and West plates, right,
The muons accumulations can be different from one plate to another, the announced results are based on the accumulation of the plates on both sides.

In position GG7, the sinking and rotation of the cone towards the vertical accentuates the effects described for position GG5.
The upper well area is outside the detection cone.
The muons concentration in the zone (3) with the intermediate well is stronger on the western plates (3); it is stronger in the zone (4) with the lower well on the East plates.
The footprint left on the plates is smaller and the mass height above the wells is large.
The muons arriving at the GG2 have been greatly absorbed before crossing it, so there is less left to detect the eastern and western sides of it.
The solid area between (3) and (4), vertical to GG7, absorbs more muons.

Analysis of the plates laid in the axis of the GG1 in GQ.



In beige, the detection cone of the plates laid in the Grand Gallery in GQ.
The southern limit of the cone not being indicated on the diagram, it is not represented.



Comparison of the BIG VOID/GG2 with the plates centered at the bottom of the Grand Gallery.

The southern limit of the cone is not indicated on the diagram, so it is not shown.
The muons concentration is significant along the entire length of the detection, with the intermediate well (3) and the lower well (4), under which the eastern and western lateral parts of the GG2 are clearly detected.
The central position of GQ allows to fully receive the vertical muons[347] crossing the void of the lower well on a height of about 20 meters after having been absorbed only on an equivalent height.
Otherwise, on the left, the muons accumulation south of (3) is perfectly longitudinal and narrower, being related to the fact that :
- the GQ plates are laid in the axis,
- that from the southern limit of the intermediate well the height of the limestone mass above is very important,
- that the East and West lateral parts of the GG2, not very high, are not detected after (3), the muons being absorbed before reaching them, the muons trajectories coming from the top.

On the other hand, the intermediate well and the central part of the GG2 are detected, making a void of about 18m height.

The emulsion plates laid in GQ are evidence of the continuity of the BIG VOID and the presence of vertical wells.

[347] As shown in blue in 4a and 4b in the diagrams on page 85.

To end this analysis of the document "2019 Scientific Report - September 2019", I quickly resume the results of the CEA team which totally confirm those of the Nagoya team.

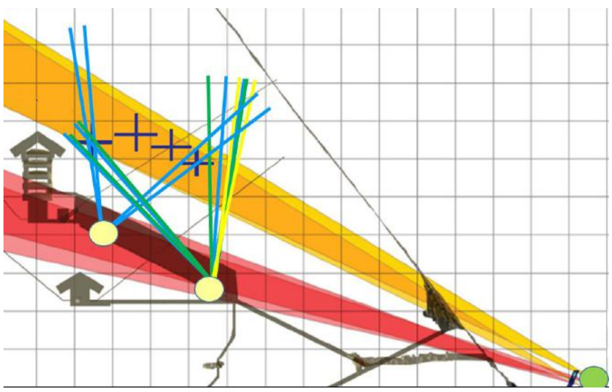
For the 2018-2019 muons collection campaign from inside the GG1, the CEA has implemented two specially built telescopes:
- The first one, named Degennes (Deg), was laid at the bottom of the GG1 and its orientation was modified three times
- The second, named Charpak (Cha), was laid at the top of the GG1 and its orientation was not changed, but a second campaign was not completed by September 2019.

Positions and orientation of the CEA telescopes inside the GG1.

The exposure times of the telescopes according to these positions and the number of data collected are summarized in the following table:

Telescope & position	X (South->North)	Y (East-> West)	Z (down->up)	Orientation	Number of days	Statistics used here (in Millions)
Degennes GG-N1	+36.0	-6.9	25.2	18.5° North	118.7	5.7
Degennes GG-N2	+36.0	-6.9	25.7	17.2° South	77.8	2.5
Degennes GG-N3	+36.0	-6.9	25.7	10.2 South	68.8	5.4
Charpak GG-S1	+6.0	+7.7	39.5	24.5° North	189.7	7.1
Charpak GG-S2	+6.0	+7.7	39.5	24.5° North	56.5	

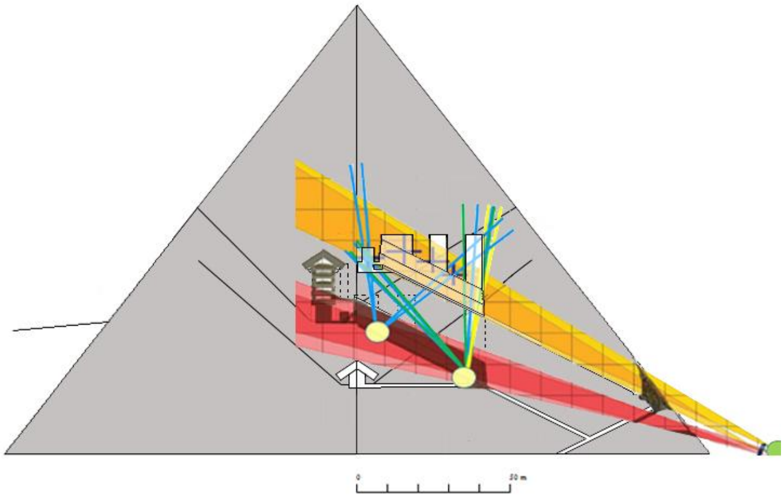
The results announced in September 2019 are based on nearly 21 million statistical data collected by the two telescopes.
The last data from Charpak were not counted, as the exposure time was too short.



The green circle on the right represents the position of the telescopes outside in 2017.
The yellow circle at the top of the GG1 represents Charpak, the yellow circle at the bottom, Degennes.

The crosses represent the epicenters of the muons peaks announced by the Nagoya team.
The oblique lines indicate the limits of the BIG VOID detected according to the orientation of the muons reception cones.

The results of the CEA in superimposition of the GG2.



North-South section of Khufu's Pyramid with, in superimposition, the diagram summarizing the results of the CEA team acquired during the ScanPyramids mission.

There is a perfect similarity between these results and those of the Nagoya team.

CONCLUSION OF THE ANALYSIS OF THE RESULTS.

During the ScanPyramids mission on Khufu's Pyramid that took place between early 2016 and September 2019, the BIG VOID was discovered by three different muography techniques:

- The scintillator, implemented by the KEK (Japan), discovered the BIG VOID from the Queen's Chamber; this technique, heavy, therefore fixed, and with only one point of view, did not have vocation to determine precisely the contour of the discovery. On the other hand, its length and its spatial position were established and are consistent with the discoveries of the two other techniques.
- The telescopes, implemented by the CEA (France), discovered the BIG VOID from the outside, then confirmed this discovery from the inside of the Grand Gallery by specifying, thanks to the quantity of statistical data collected, its length, its spatial position and its limits; these three parameters are fully consistent with those of the Nagoya team.
- The emulsion plates, implemented by Nagoya University (Japan), discovered the BIG VOID from the Queen's Chamber and the Grand Gallery from numerous positions and the data recorded by several hundred plates. This huge amount of data allowed the Nagoya team to announce a discovery with incredible and indisputable accuracy.

The only big question that these top scientists could not answer was about a subject that was no longer in their domain: ARCHITECTURE.

As I wrote at the bottom of Page 50:

"It was time to give a clear and precise answer to the scientists regarding these two famous sentences:

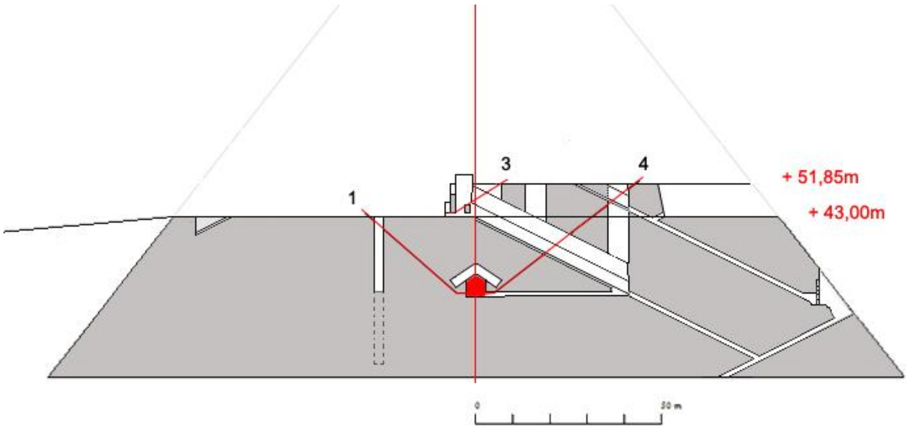
- The slope determination depends also on the architectural shapes hypothesis of SP-BV,
- SP-BV architectural shape is still undetermined."

Now you have my answer.

10 - SEQUENCES OF THE CONSTRUCTION SITE OF THE KING'S ROOM AND ITS SUPERSTRUCTURE

"Genius is simply the ability to reduce what is complicated to simplicity".
C. W. Ceram.

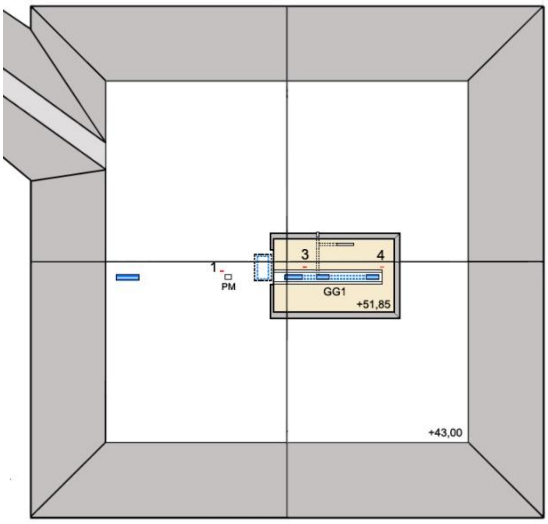
1 - Phase 1B - Hoisting of the monoliths on the external ramp up to the +43.00m level.



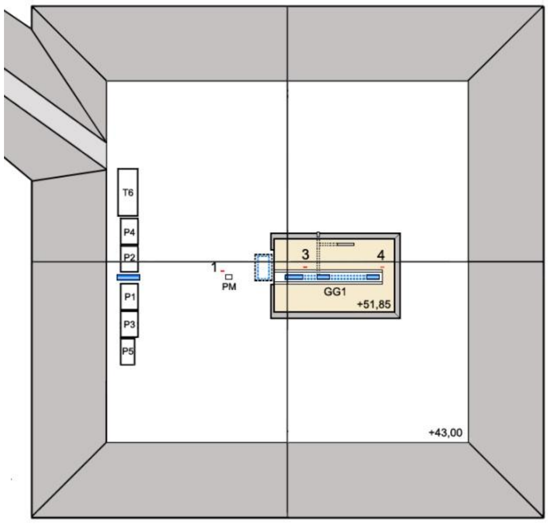
North-South section.

The monoliths are hoisted on the external ramp to the storage area reserved at the +43.00m level in the southern part of the pyramid. The GG1 and its counterweight load modulation wells are integrated into a temporary mastaba erected up to the level +51.85m, level of the 2nd ceiling[348] of the superstructure above the King's Chamber. The Queen's Chamber is temporarily used, thanks to its acoustics and in conjunction with its two shafts (1) and (4), as an intercom system linked to the counterweight system. The King's Chamber will join the intercom system in Phase 2A.

Plans of the +43,00m level.



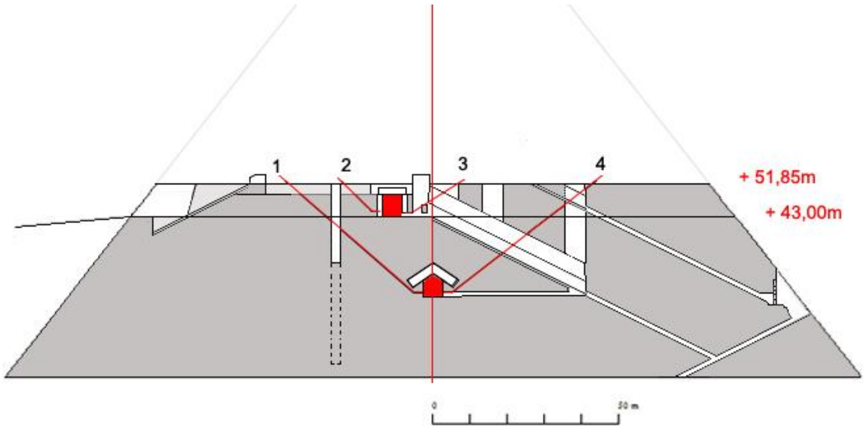
Top left, arrival of the external ramp at the +43.00m level. In the center, the provisional mastaba integrating the GG1 and its modulation wells. The future King's Chamber is at the southern foot of the mastaba. The Queen's Chamber and the outlets of its shafts are ready for use: (1) next to the motor well (PM) of the GG1, (4) next to the lower modulation well. The North shaft of the King's Chamber (3) is next to the intermediate and upper wells of the GG1.



All the monoliths were hoisted with the counterweight of the GG1. They were grouped by levels of their final setting, for the ceilings (P1), (P2), (P3), (P4) and (P5) and for the roof (T6). This arrangement was essential for the smooth running of the construction sequences of the superstructure above the King's Chamber.

348 Although the term "ceiling" is not appropriate, as I said in *Information Note No. 1* on page 23, I use it anyway for simplicity.

2 - Phase 2A - Hoisting of the beams and construction of the 1st ceiling.

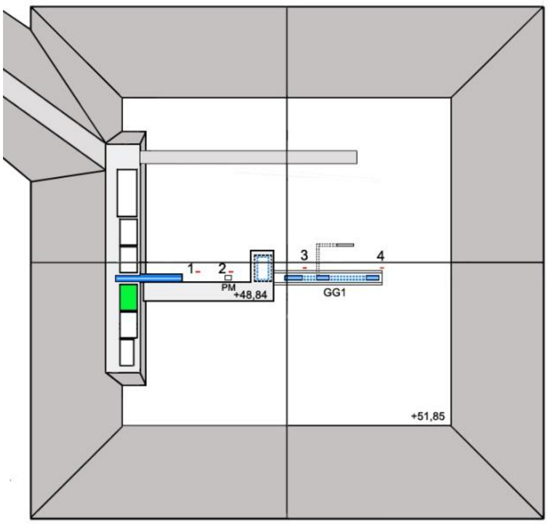


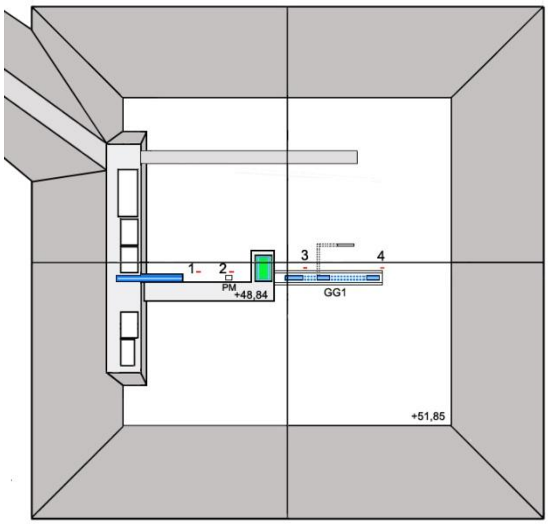
North-South section.

The pyramid was built up to the level +51.85m, level of the 2nd ceiling of the superstructure. The temporary mastaba around the GG1 and its modulation wells is drowned in the mass. Opposite the GG1, on the southern side, the monoliths are still stored on the dedicated area at the +43.00m level; the hoisting ramp/slide is built in a dedicated trench. An area, between it and the King's Chamber, has been reserved at the +48.84m level for the delivery and setting of the beams of the 1st ceiling.

The King's Chamber has joined the intercom system; shaft (1) now serves the ramp/slide arrival, shaft (2) has taken over near the motor well. Shafts (3) and (4) still serve the same modulation wells.

Plans of the +43,00m, +48,84m and +51,85m levels.





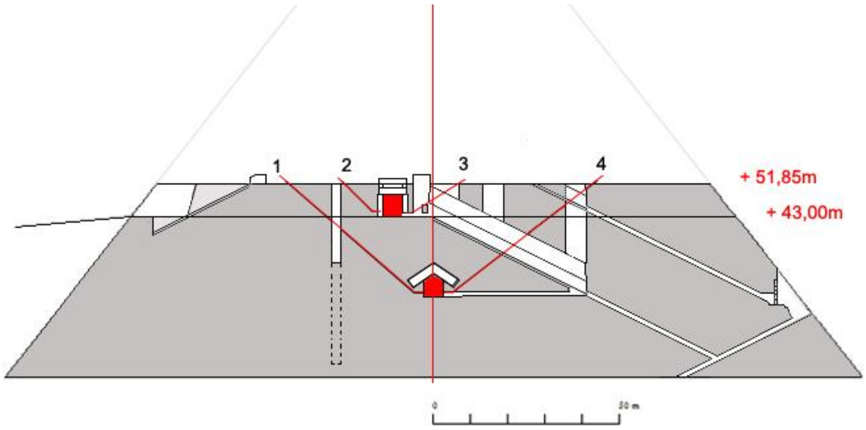
The external ramp is now extending in a trench in the body of the pyramid; it will spiral up to more than +70m and will allow building half the height of the pyramid, but especially nearly 85% of its volume[349] .

In green, the beams of the 1st ceiling on the storage area at level +43,00m. A passage area to the King's Chamber has been reserved at the level +48,84m, level of the 1st ceiling.

The 1st ceiling is now built (in green).

[349] See *Information note N°4* Page 53.

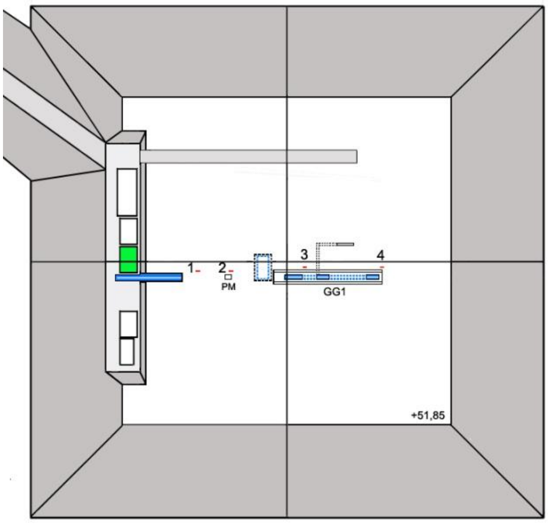
3 - Phase 2A - Hoisting of the beams and construction of the 2nd ceiling.



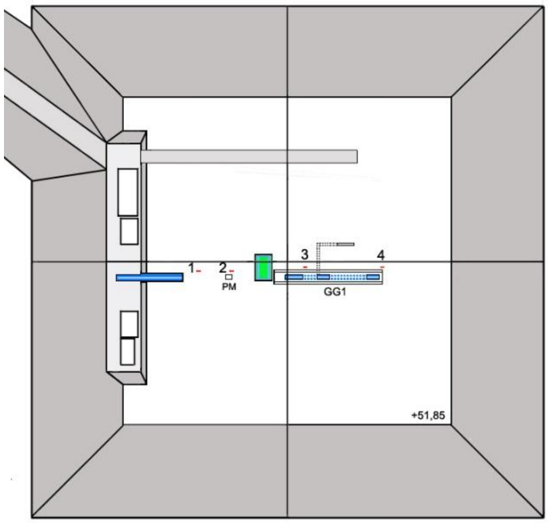
North-South section.

The area reserved at the +48.84m level for the delivery and setting of the beams of the 1st ceiling is now filled in up to the +51.85m level. The position of the four shafts is unchanged.

Plans of the +43,00m and +51,85m levels.



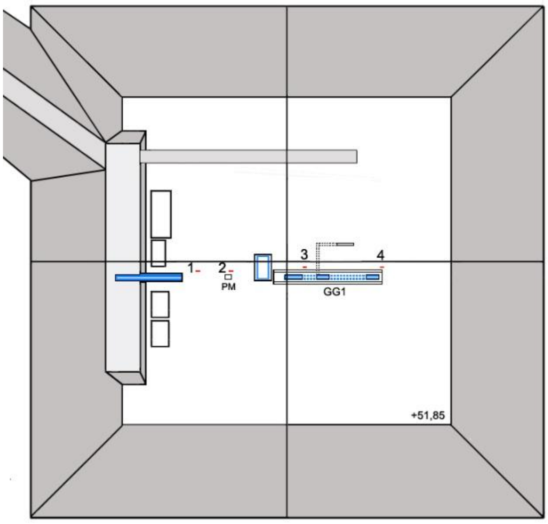
In green, the beams of the 2nd ceiling on the storage area at level +43,00m. The reserved passage area at level +48,84m is now filled up to level +51,85m, level of the 2nd ceiling.

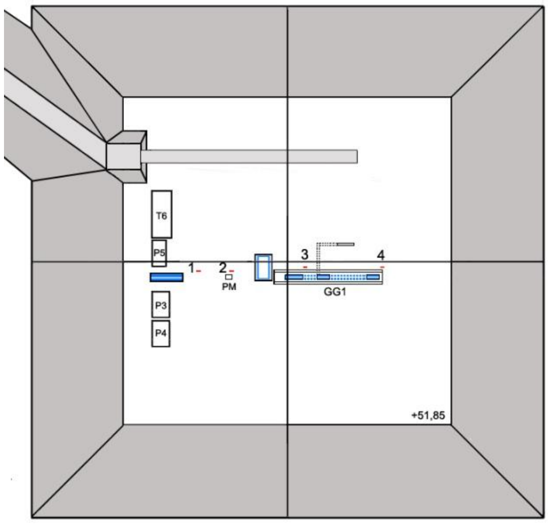


The 2nd ceiling is now built (in green).

Last process of Phase 2A.

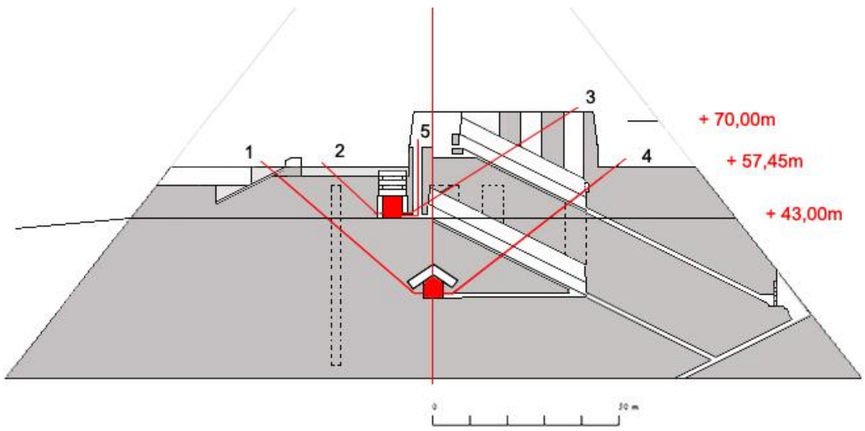
Plans of the +43,00m and +51,85m levels.





The monoliths remaining on the storage area at the +43.00m level are hoisted to the +51.85m level, those of the 3rd (P3) and 4th (P4) ceilings on the East side of the ramp/slide, those of the 5th ceiling (P5) and the roof (T6) to the West of the latter. The southern part of the pyramid between the levels +43.00m and +51.85m is filled in at the same time as the construction of the 4th section, horizontal, of the internal ramp at the level +43.00m between the southwestern and southeastern corners; a small part is reserved for the passage between the external ramp and its extension in trench.

4 - Phase 2B1 - Hoisting of the beams and construction of the 3rd ceiling.

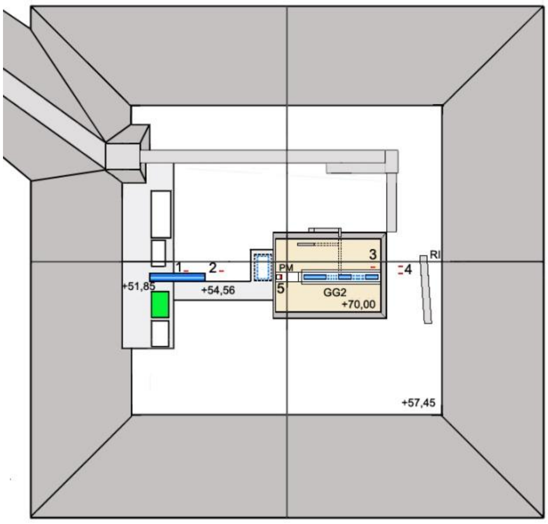


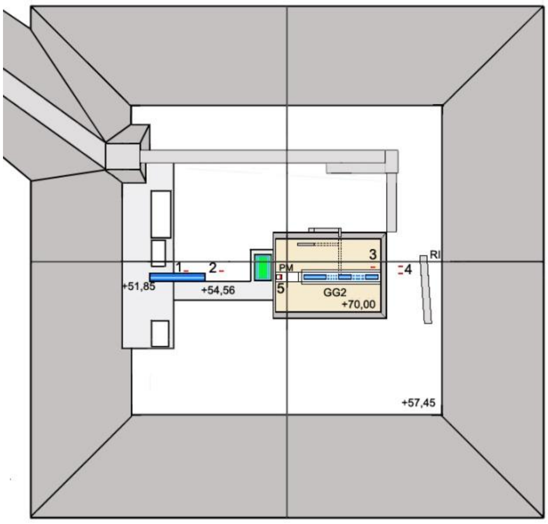
North-South section.

The pyramid was built up to the level +57.45m, the level of the 4th ceiling of the superstructure. The GG2 and its counterweight load modulation wells are integrated in a temporary mastaba erected up to the level +70.00m[350] . Opposite the GG2, on the South side, the monoliths are stored in a dedicated area at the +51.85m level; the hoisting ramp/slide is extended in a dedicated trench. An area, between it and the King's Chamber, has been reserved at level +54.56m for the delivery and setting of the beams of the 3rd ceiling. Shaft (1) overlooks the storage area and the bottom of the ramp/slide, shaft (2) overlooks the arrival levels. Shaft (3) serves the intermediate and lower modulation wells; shaft (4), doubled from the GG2, serves the interior of the latter. The motor well (5) serves the top of the GG2.

350 This level +70,00m is a minimum given as an indication, the real level must be located at approximately 2 or 3m above this one. It will be specified during a next 3D modeling.

Plans of the +51.85m, +54.56m, +57.45m and +70.00m levels.



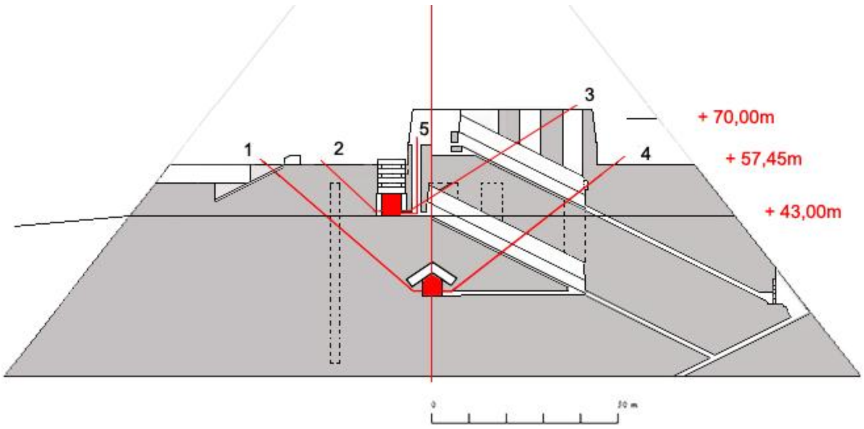


The trench ramp arrives at the +57.45m level after splitting into 2 lanes at its first right-angle turn, one section serving the western part of the pyramid, the other continuing eastward to serve this area.
The 6th section of the internal ramp reaches this level at the North-South axis, in the northern part near the trench ramp.

In green, the beams of the 3rd ceiling on the storage area at level +51,85m. A passage area to the King's Chamber has been reserved at level +54,56m, level of the 3rd ceiling.

The 3rd ceiling is now built (in green).

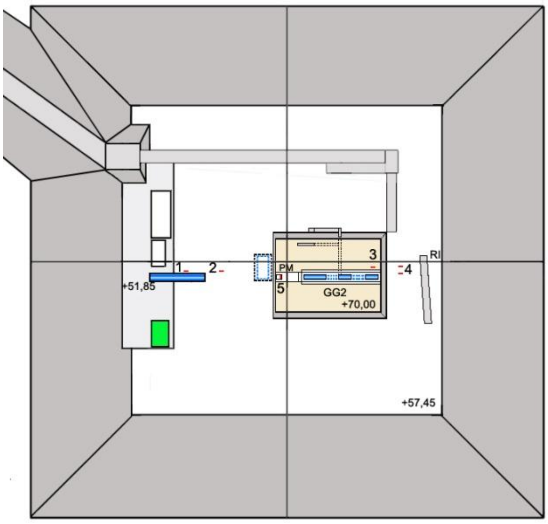
5 - Phase 2B1 - Hoisting of the beams and construction of the 4th ceiling.



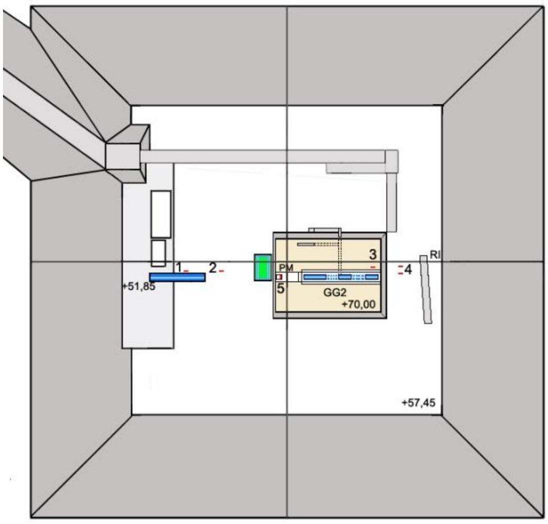
North-South section.

The area reserved at level +54.56m for the delivery and setting of the beams of the 3rd ceiling is now filled up to level +57.45m. The position of the four shafts is unchanged.

Plans of the +51.85m, +57.45m and +70.00m levels.



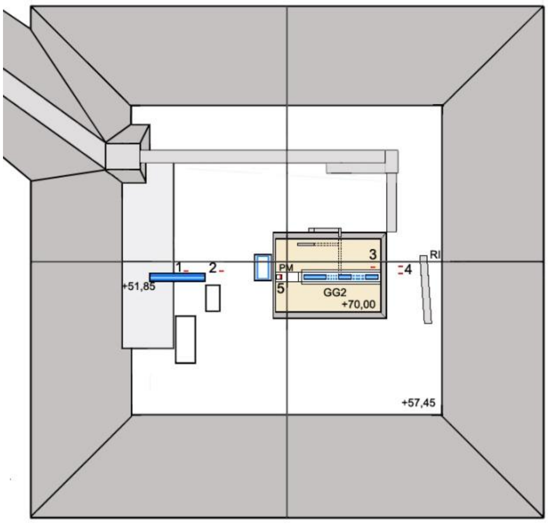
In green, the beams of the 4th ceiling on the storage area at level +51,85m. The reserved passage area at level +54,56m is now filled up to level +57,45m, level of the 4th ceiling.

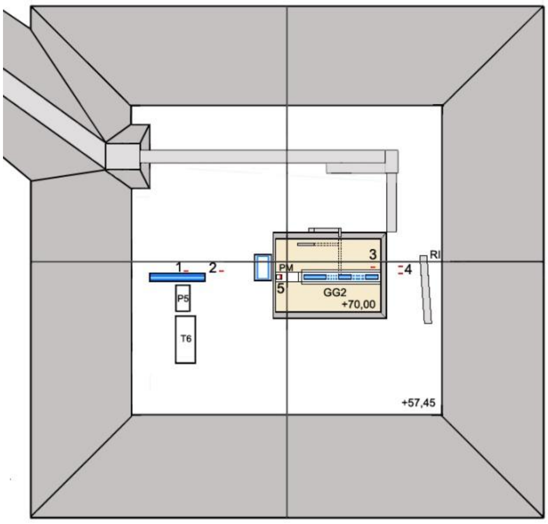


The 4th ceiling is now built (in green).

Last process of Phase 2B1.

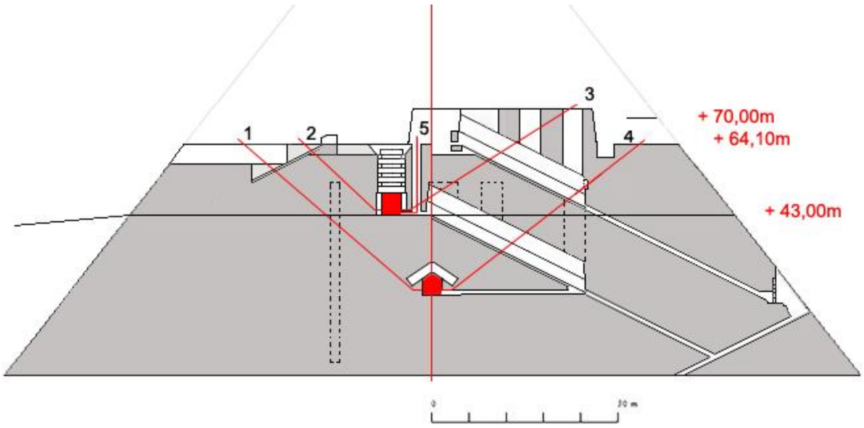
Plans of the +43,00m and +51,85m levels.





The monoliths of the 5th ceiling (P5) and the roof (T6) remaining on the storage area at the +51.85m level are hoisted to the +57.45m level, on the East side of the ramp/slide.
The southern part of the pyramid between the +51.85m and +57.45m levels is filled in.

6 - Phase 2B2 - Hoisting of the beams and construction of the 5th ceiling.

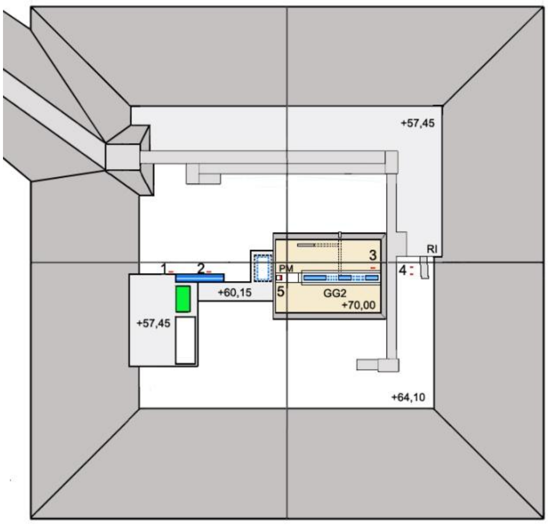


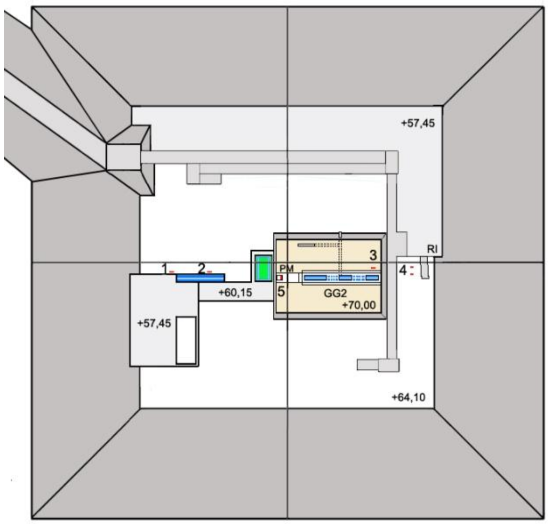
North-South section.

The pyramid was built up to the level +64.10m, the level of the underside of the junction of the roof rafters and also of the upper platform of the GG2. The temporary mastaba erected up to the level +70.00m was not modified. Opposite the GG2, on the South side, the monoliths are stored in a dedicated area at the +57.45m level; the hoisting ramp/slide is extended in a dedicated trench. An area, between it and the King's Chamber, has been reserved at level +60.15m for the delivery and setting of the beams of the 5th ceiling.

Shaft (1), extended, still overlooks the storage area and the bottom of the ramp/slide, as does shaft (2) on the incoming levels. Shaft (3), unchanged, serves the intermediate and lower modulation wells; shaft (4), doubled and extended, still serves the interior of the GG2. The motor well serves the top of the GG2.

Plans of the +57.45m, +60.15m, +64.10m and +70.00m levels.



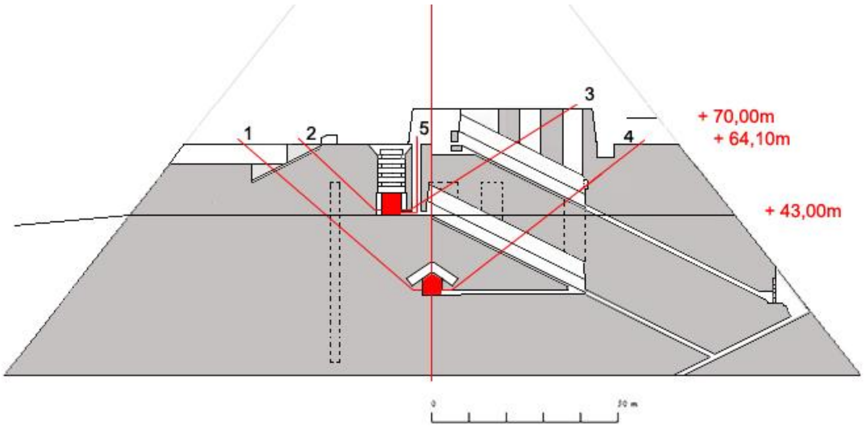


The trench ramp arrives at the +64.10m level after splitting into two lanes at its first right-angle turn, one section serving the western part of the pyramid, the other the eastern part.
The western and northwestern parts of the pyramid between the trench ramp and the faces are not built, remaining at level +57.45m. The construction of the internal ramp is suspended, at the half of the 6th section, at the level of the North-South axis, until the end of the construction of the superstructure above the King's Chamber.

In green, the beams of the 5th ceiling on the storage area at level +57,45m. A passage area to the King's Chamber has been reserved at the level +60,15m, level of the 5th ceiling.

The 5th ceiling is now built (in green).

7 - Phase 2B2 - Hoisting of the beams and construction of the roof.

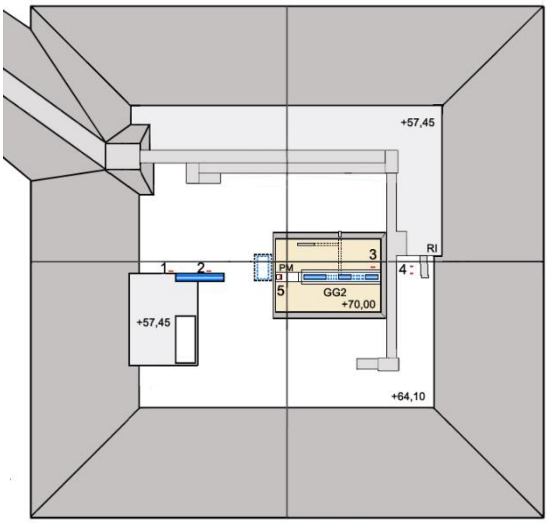


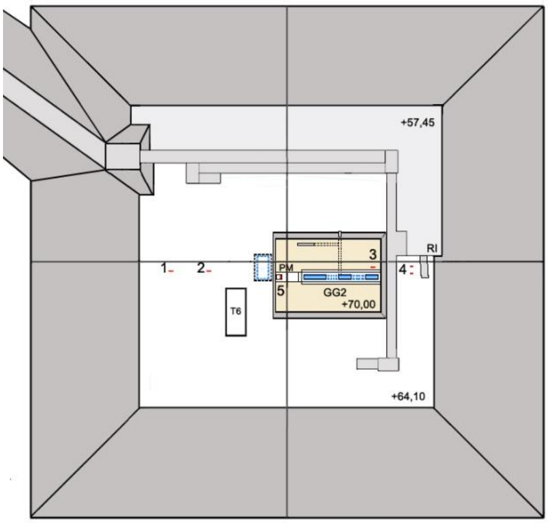
North-South section.

The area reserved at the +60.15m level for the delivery and installation of the beams of the 5th ceiling is now filled in up to the +64.10m level. The position of the four shafts is unchanged.

Last process of Phase 2B2 before construction of the roof.

Plans of the +57.45m and +64.10m levels.

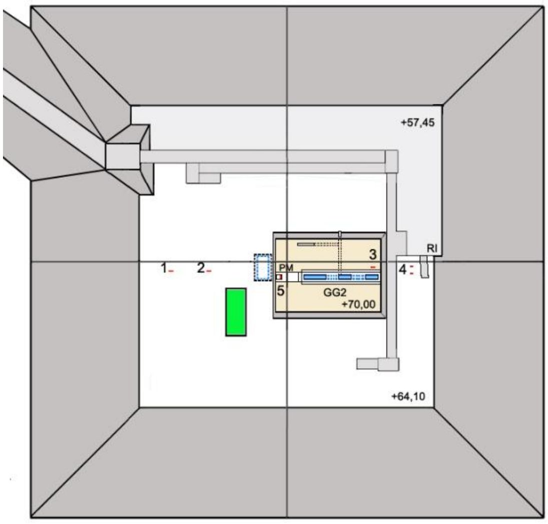




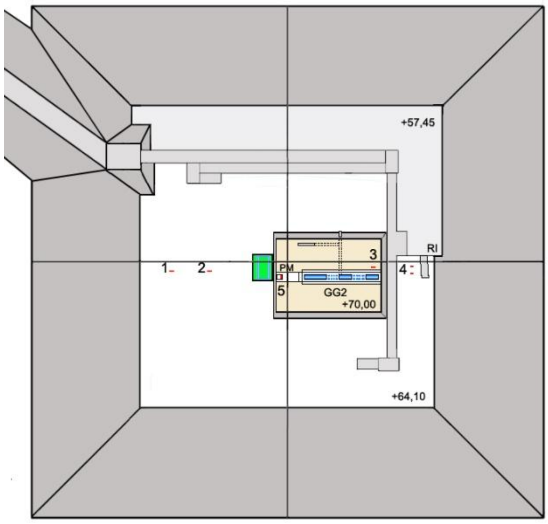
The roof beams (T6) remaining on the storage area at level +57.45m are hoisted to level +64.10m.
The southern part of the pyramid between the levels +57.45m and +64.10m is filled in, as well as the ramp/slide.

Remarkable geometric detail: the transmission station of the double shaft (4) is inserted between the trench ramp running along the North face of the mastaba and the temporary outlet of the 6th section of the internal ramp. Until the end of the construction of the superstructure above the King's Chamber, the facing blocks passing through it take a new temporary detour by joining the trench ramp crossing it a few meters away.

Plans of the +51.85m, +57.45m and +70.00m levels.

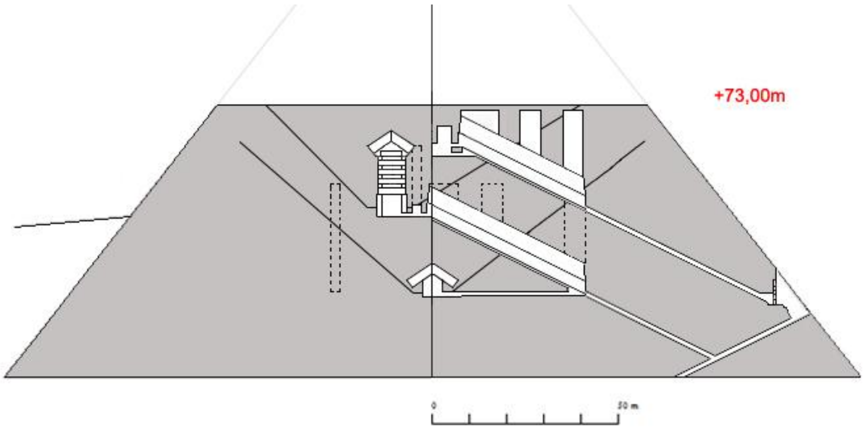


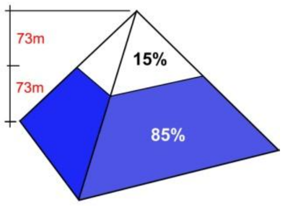
In green, the roof beams waiting at the +64.10m level.



The roof is now built[351] (in green).

End of the construction of the King's Chamber and its superstructure.





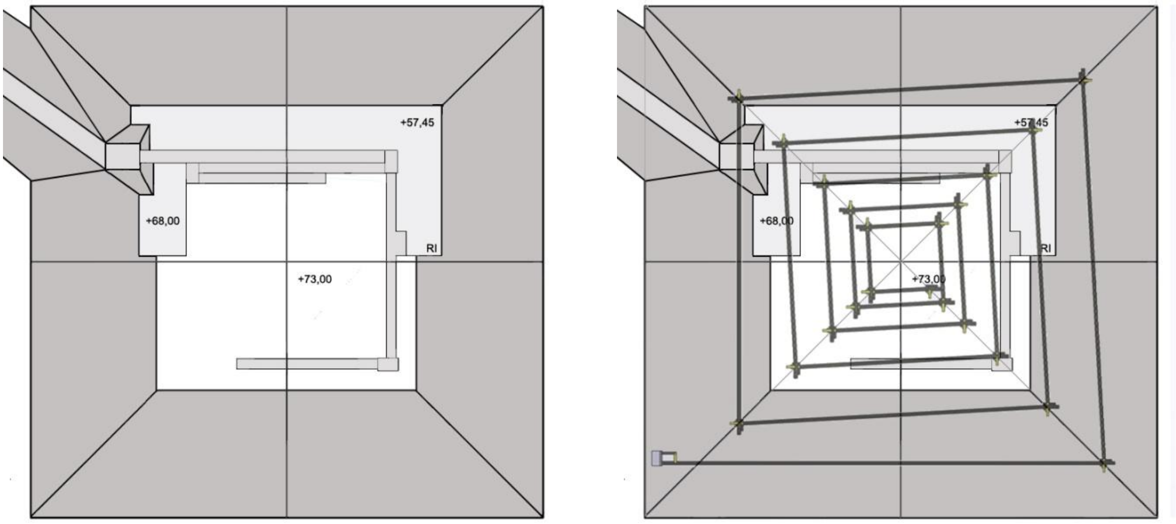
I wrote on Page 53:

"85% of the volume could be realized thanks to the short external ramp and its extension in trench which allowed reaching the level +73m, half height of the pyramid; at this level the roof of the King's Chamber is completely covered".

I can now add:

At this level, the GG2 and its temporary mastaba are also completely covered. Only 15% of the volume remains to be built without any other masonry void except for the sections of the internal ramp.

[351] The method of construction is identical to that of the rafters above the entrance on the North face and the roof of the Queen's Chamber. It will be detailed in the forthcoming document: "Khufu's Pyramid, recent discovery of a corridor under the North face by the ScanPyramids mission".



The ramp in trench allowed reaching the half-height of the pyramid, at the level +73,00m, except, temporarily, along the zones in the western part of the pyramid (+57,45m and +68,00m) on the path of the internal ramp to be built.
Its construction will resume with the filling of these areas and the trench ramp, with materials delivered from both the external and internal ramps[352] .
Above the +73.00m level, and up to the top, the internal ramp becomes the only way to deliver the limestone blocks.
A stroke of genius on the part of the designers, these blocks are the result of recycling the blocks that made up the external ramp, which was dismantled as the remaining 15% was built.

In the last paragraph of Page 56 at the end of the *Information Note N°4,* I wrote:

"Conclusion: If the position of the interior structures was directly influenced by the construction processes of the volume, their realization was totally independent of the construction of this volume; a simple but very effective conception of two distinct building sites integrated one into the other".

This conclusion makes sense now.

[352] The progress of this stage of the work will be detailed in the forthcoming document: "Khufu's Pyramid, recent discovery of a cavity under the northeastern edge by the ScanPyramids mission".

11 - HOISTING OF MONOLITHS: TABLES OF REQUIRED FORCES AND COUNTERWEIGHTS' LOADS ACCORDING TO THE PHASES

Remark:

All the computations summarized in the following tables have been made by me on the basis of the numerous works already done by Denis Denoël in the years 2016 and 2017. The methods were respected for these last computations which take into account the very last updates in the definition of the counterweight system made between 2017 and 2022; this concern in particular the relays, the quality of the material used for these and the weight of the motors implemented. The sketches illustrating these tables are by Denis Denoël but they have been modified by me to fit with the latest update of the counterweight system.

REMINDER OF THE PHASES, DATA AND PARAMETERS OF THE COMPONENTS.

Phase 1A:

Hoisting the monoliths from the port to a storage area at the base of the external ramp.
Use of a counterweight running in a trench dug in the bedrock in the axis and in continuity of a ramp linking the port to the storage area.
The port ramp has a slope of approximately 8.5% (4.80°) and the counterweight ramp-slide a slope of 50% (26.57°).
The technique of direct traction by the counterweight is implemented and its load is adjustable. Its rearmament is ensured by a motor, a block of granite of 3,5t moving in a vertical well; this motor is rearmed concomitantly with the hoisting of the monolith.

Phase 1B:

Hoisting of the monoliths from the base of the external ramp to a storage area located at level +43m in the southern part of the pyramid.
Use of a counterweight running in the Grand Gallery known as the GG1.
The external ramp has a slope of approximately 8.5% (4.80°) and the GG1 has a slope of 50% (26.57°).
The technique of direct traction by the counterweight is implemented. Its total base weight is 19t but is adjustable by adding blocks-lests of 2.25t, up to 9 for a maximum of 20t.
The counterweight is rearmed by a motor, three granite blocks of 3.5t moving in a vertical well; this motor is rearmed concomitantly with the hoisting of the monolith.

Phase 2A:

Hoisting of the monoliths of the storage area from level +43m to level 48,84m (1st ceiling) and level +51,85m (2nd ceiling and new storage area).
Use of a counterweight running in the Grand Gallery known as the GG1.
The monolith hoisting ramp-slide faces the GG1 and has a slope of 50% (26.57°).
The 180° return technique traction by the counterweight is implemented. Its total base weight is 19t but is adjustable by adding blocks-lests of 2.25t, up to 9 for a maximum of 20t.
A motor, made of 1 to 3 blocks of 2.35t, moving in a vertical well located between the GG1 and the ramp-slide brings the additional force necessary to the hoisting of the monoliths. This motor is rearmed concomitantly with the counterweight at its base load. It is also used for the operations of rearmament of the counterweight.

Phase 2B1:

Hoisting of the monoliths of the storage area from level +51,85m to level 54,56m (3rd ceiling) and level +57,45m (4th ceiling and new storage area).
Use of a counterweight running in a second Grand Gallery (the BIG VOID) called the GG2.
The monolith hoisting ramp-slide faces the GG2 and has a slope of 50% (26.57°).
The 180° return technique traction by the counterweight is implemented. Its total base weight is 19t but is adjustable by adding blocks-lests of 2.25t, up to 9 for a maximum of 20t.
A motor, made of 1 to 3 blocks of 2.35t, moving in a vertical well between the GG2 and the King's Chamber brings the additional force needed for the hoisting of the monoliths. This motor is rearmed concomitantly with the counterweight at its base load. It is also used for the operations of rearmament of the counterweight.

Phase 2B2:

Hoisting of the monoliths of the storage area from level +57,45m to level 60,15m (5th ceiling) and level +64,10m (new storage area before construction of the rafter roof).
Use of a counterweight running in the GG2.
All other parameters are identical to those of Phase 2B1.

Data and parameters of the components:

For the rearmament of the counterweight of the GG1[353] or the GG2, the blocks-lests loading the counterweight platform are dimensioned to be all laid directly in one layer, thus without the need for lifting. In the computations presented the blocks-lest weigh 2,500kg (2.5t). It takes 17 blocks to rearm the counterweight. In reality, with this load, the system is almost at equilibrium. To start a reset, it is necessary to add an eighteenth block of one ton. The rearmament is then controlled by a team that slows down the descent of the counterweight platform.

The three blocks-lests of the GG1 motor weighed 3,500kg (3,5t) each. Later, they were shortened by one cubit (0.52m) to be reused, weighing 2,350kg (2.35t), as the motor of the GG2.

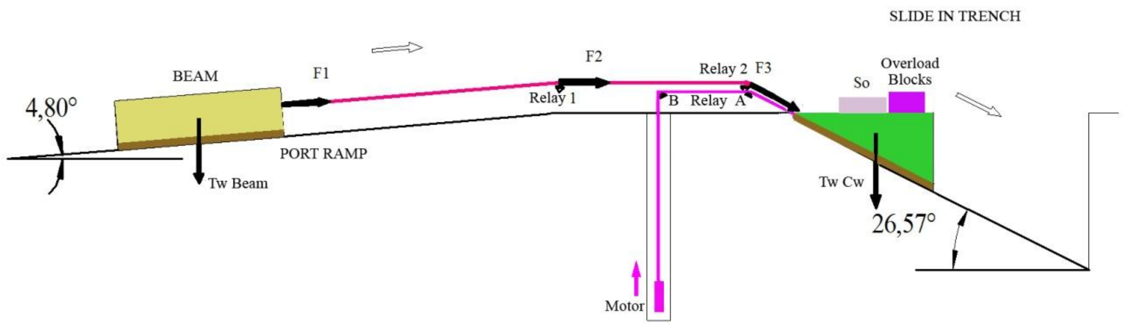
The nine overload blocks-lests for the GG1 and the GG2 counterweight trolley were sized for this study. As an example: just an extension of one cubit (0,52m) of each of the nine blocks would bring about 6.700kg (6,7t) of additional overload without any modification of the counterweight trolley. This brings some margin in reserve.

Finally, the computations are based on the weight of the lightest and heaviest beam. Intermediate weights of 30,000kg, 40,000kg and 50,000kg were studied to get an overall idea of the requirements according to the actual weight of all the monoliths put in place in the superstructure above the King's Chamber.

[353] Except in Phase 1B

COUNTERWEIGHT ON THE PLATEAU
Phase 1A

Counterweight: direct traction of the beam
+ Direct traction of the Motor for its rearmament



Data										
Tw beam	Slope Port Ramp	Slope Slide in trench	Motor Well	Coef Relay Pp lubricat	Tw sled only	Tw Trol Pla only	Tw Rope ramp	Tw Motor 1 Lest x 3500	Tw Base Load So Cw 2 Blocks	Tw Block Lest Cw
Kg	Deg	Deg	Deg		Kg	Kg	Kg	Kg	Kg	Kg
25.000	4,80	26,57	90,00	0,10	500	2000	4000	3500	5000	2500
30.000	4,80	26,57	90,00	0,10	500	2000	4000	3500	5000	2500
40.000	4,80	26,57	90,00	0,10	500	2000	4000	3500	5000	2500
50.000	4,80	26,57	90,00	0,10	500	2000	4000	3500	5000	2500
62.000	4,80	26,57	90,00	0,10	500	2000	4000	3500	5000	2500

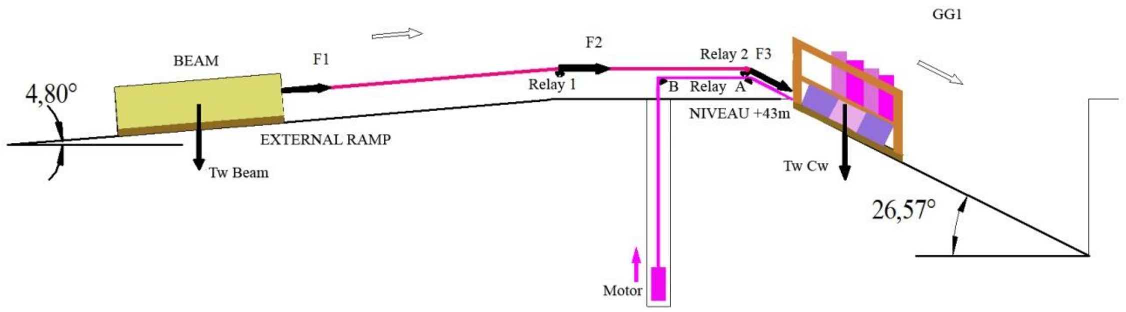
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation												
Tw beam + Sled +Rope	Tw Motor	F1 Beam	F2 Beam	F3 Beam	FB Mot	FA Mot	F Total	Tw Cw Base So	F Tract Cw Base So	Need F	Added Lest on Cw	Nb Blocks Lest Cw
Kg	Kg							Kg			Kg	
	3500				3850	4235	4235	7000	3130	1105	2315	1
31500	3500	2662	2928	3221	3850	4235	7455	7000	3130	4325	9671	4
36500	3500	3084	3392	3322	3850	4235	7627	7000	3130	4497	10055	4
46500	3500	3929	4322	4754	3850	4235	8989	7000	3130	5859	13101	5,5
56500	3500	4774	5251	5776	3850	4235	10011	7000	3130	6881	15386	6,5
66500	3500	5619	6181	6800	3850	4235	11035	7000	3130	7905	17674	7

GG1

Phase 1B[354]

Counterweight: direct traction of the beam
+ Direct traction of the Motor for its rearmament



Data									
Tw beam	Slope Extern Ramp	Slope GG1	Motor Well	Coef Relay Pp lubricat	Tw sled only	Tw Trol Cw only	Tw Rope ramp	Tw Motor 3 Lests x 3500	Tw Load Base Cw
Kg	Deg	Deg	Deg		Kg	Kg	Kg	Kg	Kg
25.000	4,80	26,57	90,00	0,10	500	3000	2000	10500	16000
30.000	4,80	26,57	90,00	0,10	500	3000	2000	10500	16000
40.000	4,80	26,57	90,00	0,10	500	3000	2000	10500	16000
50.000	4,80	26,57	90,00	0,10	500	3000	2000	10500	16000
62.000	4,80	26,57	90,00	0,10	500	3000	2000	10500	16000

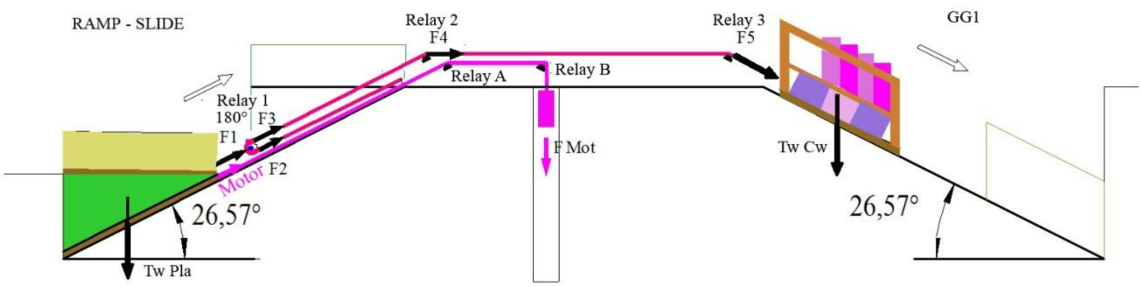
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation													
Tw beam + Sled + Rope	Tw Motor	F1 Beam	F2 Beam	F3 Beam	FB Mot	FA Mot	F Total	Tw Cw	F Tract Cw	Need F	Contrib F Tract Hum	Added Lest on Cw	Nb Blocks Lest Cw
Kg	Kg							Kg				Kg	
0	10500				11550	12705	12705	19000	8496	4209	- 4234	0	0
27500	10500	2323	2556	2811	11550	12705	15516	19000	8496	7020		15700	7
32500	10500	2746	3020	3322	11550	12705	16027	19000	8496	7531		16842	7,5
42500	10500	3591	3950	4345	11550	12705	17050	19000	8496	8554		19127	8,5
52500	10500	4436	4880	5368	11550	12705	18073	19000	8496	9577	-1415	20000	9
62500	10500	5281	5809	6390	11550	12705	19095	19000	8496	10600	-3703	20000	9

354 See diagrams on page 62

GG1
Phase 2A[355]

Counterweight: 180° return technique traction of the beam
Motor: direct traction of the beam



Data										
Tw beam	Slope Ramp Slide	Slope GG1	Well Motor	Relay coef 180° Pp lubricant	Relay coef Pp lubricant	Tw Trol Pla only	Tw Trol Cw only	Tw Rope	Tw Motor 1 à 3 weights x 2350	Tw Load Base Cw
Kg	Deg	Deg	Deg			Kg	Kg	Kg	Kg	Kg
25.000	26,57	26,57	90,00	0,20	0,10	2000	3000	1000	2350	16000
30.000	26,57	26,57	90,00	0,20	0,10	2000	3000	1000	4700	16000
40.000	26,57	26,57	90,00	0,20	0,10	2000	3000	1000	7050	16000
50.000	26,57	26,57	90,00	0,20	0,10	2000	3000	1000	7050	16000
62.000	26,57	26,57	90,00	0,20	0,10	2000	3000	1000	7050	16000

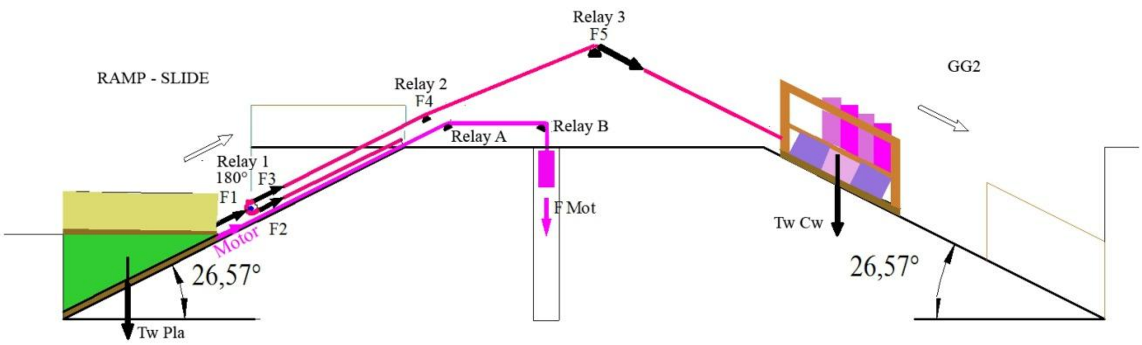
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation											
Tw beam + Pla + Cord	- F Motor 2 returns A B 1 to 3 weights	F1 Beam	F2 Beam	F3 Beam	F4 Beam	F5 Beam	Tw Cw	F Tract Cw	Need F	Lest Suppl on Cw	NB Blocks Lest Cw x 2250
Kg							Kg			Kg	
28000	-1903	10618	5309	6370	7007	7708	19000	8496	0	0	0
33000	-3806	10951	5475	6570	7227	7950	19000	8496	0	0	0
43000	-5710	13519	6759	8110	8921	9813	19000	8496	1317	2945	2
53000	-5710	17991	8995	10794	11873	13060	19000	8496	4564	10207	5
65000	-5710	23358	11679	14014	15415	16956	19000	8496	8460	18919	9

[355] See diagrams on page 59

GG2
Phases 2B1 and 2B2[356]

Counterweight: 180° return technique traction of the beam
Motor: direct traction of the beam



Data										
Tw beam	Slope Ramp Slide	Slope GG2	Well Motor	Relay coef 180° Pp lubricat	Relay coef Pp lubricat	Tw Trol Pla only	Tw Trol Cw only	Tw Rope	Tw Motor 1 à 3 weights x 2350	Tw Load Base Cw
Kg	Deg	Deg	Deg			Kg	Kg	Kg	Kg	Kg
25.000	26,57	26,57	90,00	0,20	0,10	2000	3000	1000	2350	16000
30.000	26,57	26,57	90,00	0,20	0,10	2000	3000	1000	4700	16000
40.000	26,57	26,57	90,00	0,20	0,10	2000	3000	1000	7050	16000
50.000	26,57	26,57	90,00	0,20	0,10	2000	3000	1000	7050	16000

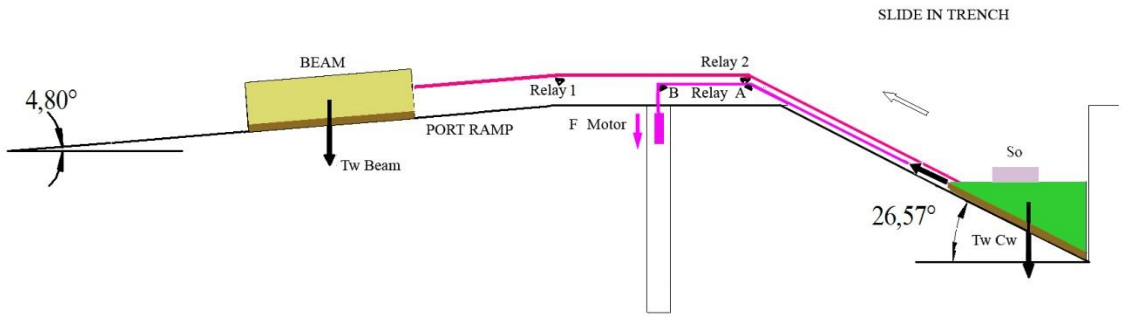
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation											
Tw beam + Pla + Rop	- F Motor 2 relays A B 1 to 3 lests	F1 Beam	F2 Beam	F3 Beam	F4 Beam	F5 Beam	Tw Cw	F Tract Cw	Need F	Lest Suppl on Cw	Nb Blocks Lest Cw x 2250
Kg							Kg			Kg	
28000	-1903	10618	5309	6370	7007	7708	19000	8496	0	0	0
33000	-3806	10951	5475	6570	7227	7950	19000	8496	0	0	0
43000	-5710	13519	6759	8110	8921	9813	19000	8496	1317	2945	2
53000	-5710	17991	8995	10794	11873	13060	19000	8496	4564	10206	5

[356] See diagrams on pages 60 and 61

COUNTERWEIGHT ON THE PLATEAU
Phase 1A

Platform-Counterweight Rearmament
With direct traction by the Motor



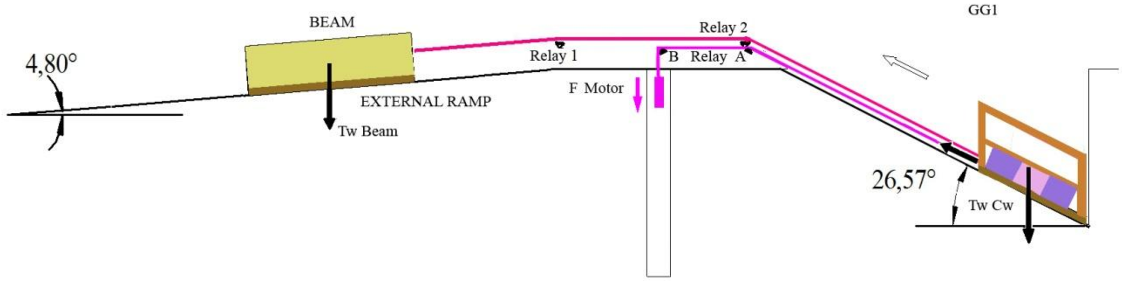
Data									
Tw beam	Well Motor	Slope Slide in trench	Coef Relay Pp lubricant	Tw sled only	Tw Rope ramp	Tw Motor 1 lest x 3500	Tw Trol Pla only	Tw Load Base So Cw	Tw Block Lest Cw
Kg	Deg	Deg		Kg	Kg	Kg	Kg	Kg	Kg
25.000	90,00	26,57	0,10	500	4000	3500	2000	5000	2500
30.000	90,00	26,57	0,10	500	4000	3500	2000	5000	2500
40.000	90,00	26,57	0,10	500	4000	3500	2000	5000	2500
50.000	90,00	26,57	0,10	500	4000	3500	2000	5000	2500
62.000	90,00	26,57	0,10	500	4000	3500	2000	5000	2500

Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation											
Tw beam + Sled + Rope	Tw Motor	F1	F2	F3	FA Mot	FB Mot	F Total Mot	Tw Total Cw	Need F Rearm Cw	Contri F Tract Hum	Nb Hom Direct Tract
Kg	Kg							Kg		Kg	
0	3500	0	0	0	3150	2835	2835	7000	3130	295	5

GG1
Phase 1B[357]

Counterweight rearmament
With direct traction by the Motor



Data									
Tw beam	Well Motor	Slope Slide in trench	Coef Relay Pp lubricant	Tw sled only	Tw Rope ramp	Tw Motor 1 lest x 3500	Tw Trol Cw only	Tw Load Base CW	Tw Total Cw
Kg	Deg	Deg		Kg	Kg	Kg	Kg	Kg	Kg
	90,00	26,57	0,10	500	2000	3500	3000	16000	19000

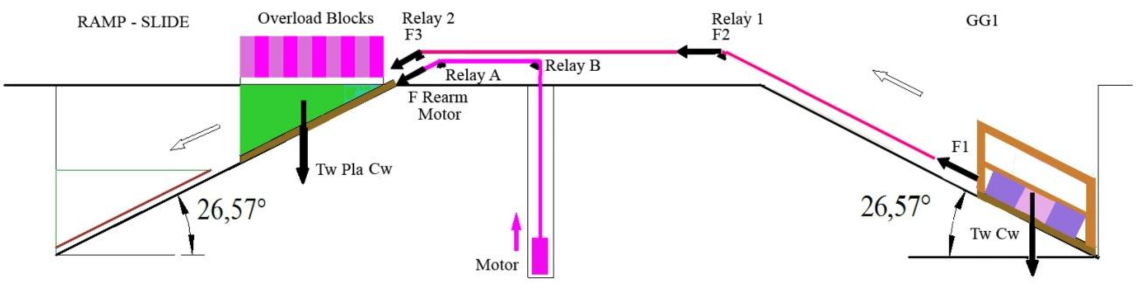
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation											
Tw beam + Sled + Rope	Tw Motor	F1	F2	F3	FA Mot	FB Mot	F Total Mot	Tw Total Cw	Need F Rearm Cw	Contri F Tract Hum	Nb Hom Direct Tract
Kg	Kg									Kg	
0	10500	0	0	0	9450	8505	8505	19000	8496	0	0

[357] See diagrams on page 62

GG1
Phase 2A[358]

Counterweight + Motor Rearmament
With the Hoisting Platform converted into a direct traction counterweight
First traction of the Counterweight



Data								
Slope Ramp Slide	Slope GG1	Well Motor	Relay coef Pp lubricat	Tw 1 Block Lest Pla-Cw	Tw Trol Pla-Cw only	Tw Rope	Tw Motor 1 à 3 weights x 2350	Tw Load Base Cw
Deg	Deg	Deg		Kg	Kg	Kg	Kg	Kg
26,57	26,57	90,00	0,10	2500	2000	1000	7050	19000

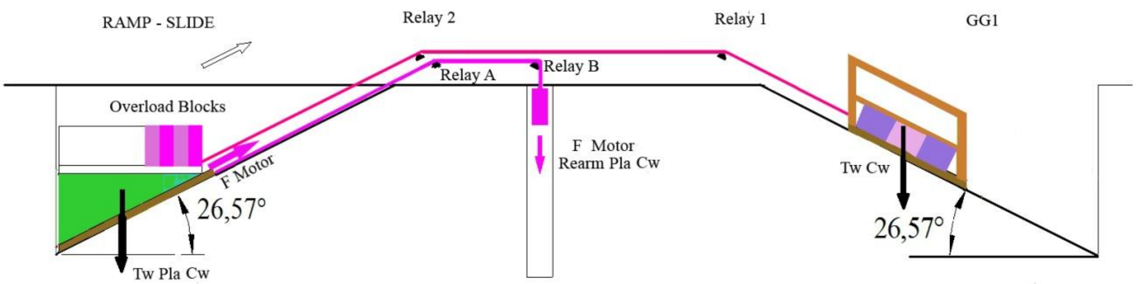
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation										
Tw Cw Base + Rope	Tw Motor	F1 Cw	F2 Cw	F3 Cw	FA Mot	FB Mot	Need F Total Cw + Mot	Tw Trol Pla-Cw + Blocks Lest	Tw Blocks Lest On Pla-Cw	Nb Blocks Lest On Pla-Cw x 2500
Kg	Kg							Kg	Kg	
20000	7050	8944	9838	10820	8250	9075	19895	44487	42487	17

358 See example 4th ceiling Pages 71 to 73

GG1
Phase 2A[359]

Hoisting Platform Rearmament
For the Second traction of the Counterweight
Direct traction with the Motor



Data								
Slope Ramp Slide	Slope GG1	Well Motor	Relay coef Pp lubricat	Tw 1 Block Lest Pla-Cw	Tw Trol Pla-Cw only	Tw Rope	Tw Motor 1 à 3 Lests 2350	Tw Load Base on Pla-Cw
Deg	Deg	Deg		Kg	Kg	Kg	Kg	Kg
26,57	26,57	90,00	0,10	2500	2000	500	7050	0

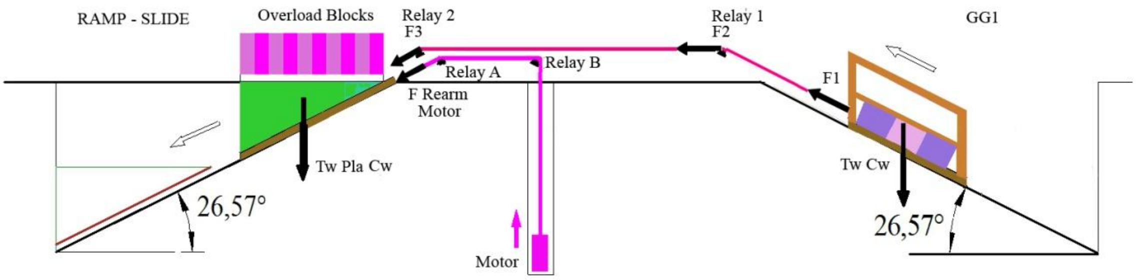
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation										
Tw Pla-Cw Base + Rope	Tw Motor	F1	F2	F3	FA Mot	FB Mot	F Total Dispo with Mot	Tw Trol Pla-Cw + Lest Tractable	Tw Blocks Lest On Pla-Cw	Nb Blocks Lest On Pla-Cw x 2500
Kg	Kg							Kg	Kg	
2500	7050				6345	5710	5710	12769	10269	4

[359] See example 4th ceiling Pages 71 to 73

GG1
Phase 2A[360]

Counterweight + Motor Rearmament
With the Hoisting Platform converted into a direct traction counterweight
Second traction of the Counterweight



Data								
Slope Ramp Slide	Slope GG1	Well Motor	Relay coef Pp lubricant	Tw 1 Block Lest Pla-Cw	Tw Trol Pla-CWp only	Tw Rope	Tw Motor 1 à 3 weights x 2350	Tw Load Base Cw
Deg	Deg	Deg		Kg	Kg	Kg	Kg	Kg
26,57	26,57	90,00	0,10	2500	2000	1000	7050	19000

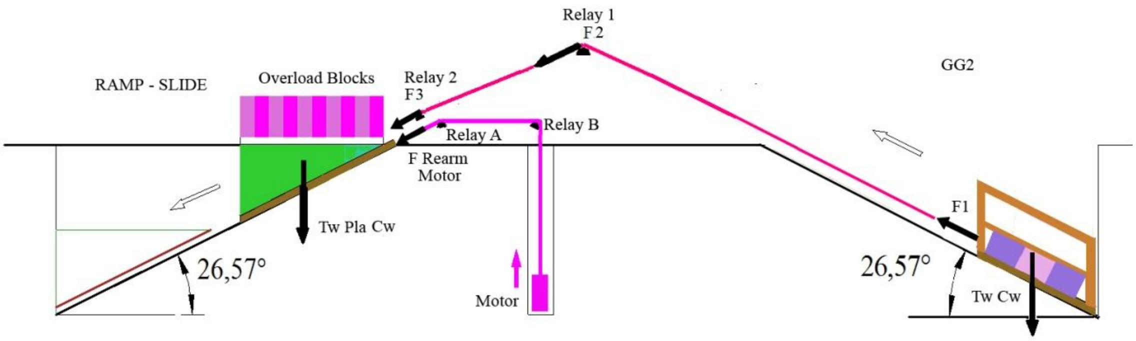
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation										
Tw Cw Base + Rope	Tw Motor	F1	F2	F3	FA Mot	FB Mot	Need F TotalCw + Mot	Tw Trol Pla-Cw + Blocks Lest	Tw Blocks Lest On Pla-Cw	Nb Blocks Lest On Pla-Cw x 2500
Kg	Kg							Kg	Kg	
20000	7050	8944	9838	10820	8250	9075	19895	44487	42487	17

360 See example 4th ceiling Pages 71 to 73

GG2
Phases 2B1 and 2B2[361]

Counterweight + Motor Rearmament
With hoisting platform converted into a direct traction counterweight
First traction of the Counterweight



Data								
Slope Ramp Slide	Slope GG2	Well Motor	Relay coef Pp lubricant	Tw 1 Block Lest Pla-Cw	Tw Trol Pla-Cp only	Tw Rope	Tw Motor 1 à 3 weights x 2350	Tw Load Base Cw
Deg	Deg	Deg		Kg	Kg	Kg	Kg	Kg
26,57	26,57	90,00	0,10	2500	2000	1000	7050	19000

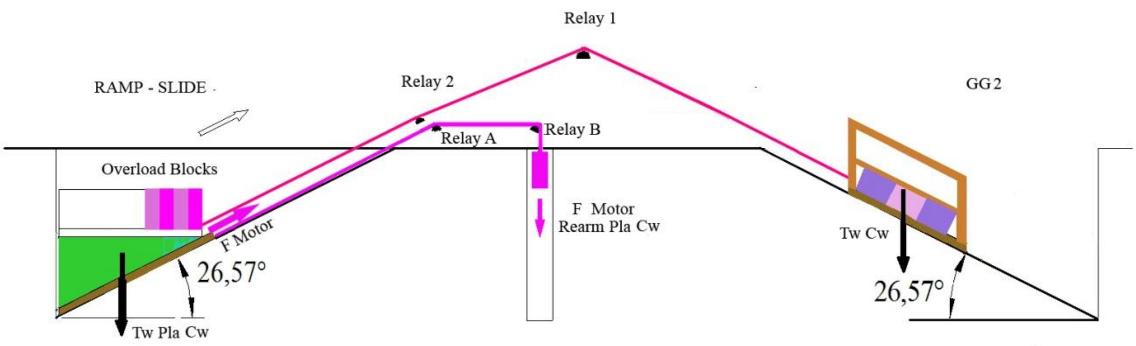
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation										
Tw Cw Base + Rope	Tw Motor	F1	F2	F3	FA Mot	FB Mot	Need F TotalCw + Mot	Tw Trol Pla-Cw + Blocks Lest	Tw Blocks Lest On Pla-Cw	Nb Blocks Lest On Pla-Cw x 2500
Kg	Kg							Kg	Kg	
20000	7050	8944	9838	10820	8250	9075	19895	44487	42487	17

[361] See example 4th ceiling Pages 71 to 73

GG2
Phase 2B1 and 2B2[362]

Hoisting platform Rearmament
For the Second traction of the Counterweight
Direct traction with Motor



Data								
Slope Ramp Slide	Slope GG2	Well Motor	Relay coef Pp lubricant	Tw 1 Block Lest Pla-Cw	Tw Trol Pla-Cw only	Tw Rope	Tw Motor 1 à 3 weights x 2350	Tw Load Base on Pla-Cw
Deg	Deg	Deg		Kg	Kg	Kg	Kg	Kg
26,57	26,57	90,00	0,10	2500	2000	500	7050	0

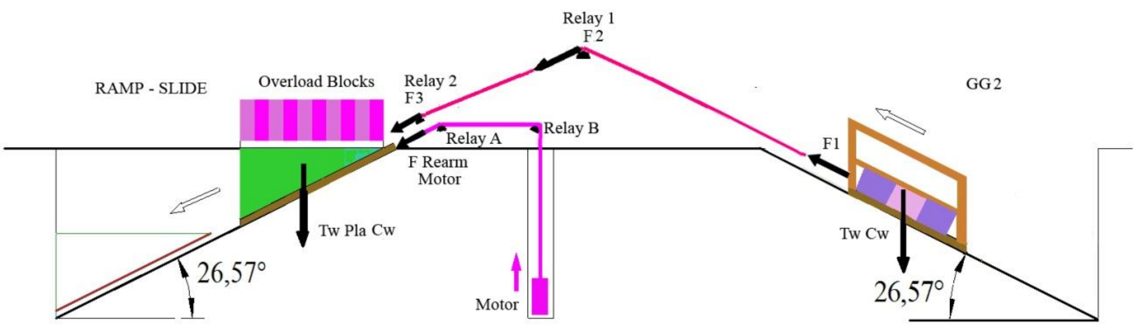
Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation										
Tw Pla-Cw Base + Rope	Tw Motor	F1	F2	F3	FA Mot	FB Mot	F Total Dispo with Mot	Tw Trol Pla-Cw + Lest Tractable	Tw Blocks Lest On Pla-Cw	Nb Blocks Lest On Pla-Cw x 2500
Kg	Kg							Kg	Kg	
2500	7050				6345	5710	5710	12769	10269	4

[362] See example 4th ceiling Pages 71 to 73

GG2
Phase 2B1 and 2B2[363]

Counterweight + Motor Rearmament
With hoisting platform converted into a direct traction counterweight
Second traction of the Counterweight



Data								
Slope Ramp Slide	Slope GG2	Well Motor	Relay coef Pp lubricat	Tw 1 Block Lest Pla-Cw	Tw Trol Pla-Cw only	Tw Rope	Tw Motor 1 à 3 Lests x 2350	Tw Load Base Cw
Deg	Deg	Deg		Kg	Kg	Kg	Kg	Kg
26,57	26,57	90,00	0,10	2500	2000	1000	7050	19000

Conversions		
4,80°	26,57°	90,00°
0,0845	0,4472	1

Computation										
Tw Cw Base + Rope	Tw Motor	F1	F2	F3	FA Mot	FB Mot	Need F Total Cw + Mot	Tw Trol Pla-Cw + Blocks Lest	Tw Blocks Lest On Pla-Cw	Nb Blocks Lest On Pla-Cw x 2500
Kg	Kg							Kg	Kg	
20000	7050	8944	9838	10820	8250	9075	19895	44487	42487	17

[363] See example 4th ceiling Pages 71 to 73

12 – FIRST CLUES SUPPORTING SOME OF THE PROPOSALS PUT FORWARD

1 - Upper well of the GG1.

Among the documents Pierre Delétie[364] gave us[365] in 2000 regarding the microgravimetry mission carried out in 1986/87 under the EDF Foundation aegis, there was the contribution[366] of Professor Hui Duong Bui[367] , of the Academy of Sciences, made during an International Symposium[368] which took place from 19 to 23 September 1988 in Athens. This document had a considerable impact on my commitment to pursue my work on solving the enigma of the construction of Khufu's Pyramid because it officially mentioned results that supported the idea of an ascending spiral ramp[369] inside the pyramid.

That said, other results were also announced, regarding measurements taken inside the Grand Gallery[370] , which have always puzzled me. I am reporting below copies of the two relevant excerpts.

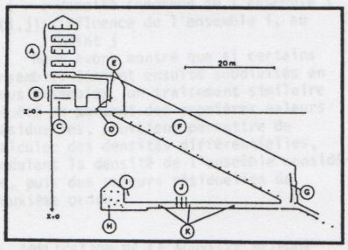
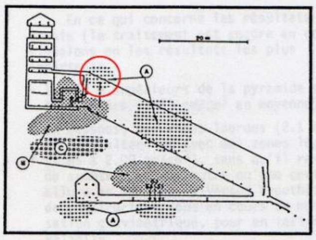


Fig. 2

Vue en coupe des points de mesure à l'intérieur des chambres.
(A) Chambre de décharge
(B) Echafaudages
(C) Chambre du Roi
(D) Tunnel de Caviglia
(E) Profils en face Sud
(F) Grande galerie
(G) Profils en face Nord
(H) Chambre de la Reine
(I) Tunnel
(J) Microforages
(K) Mesures de gradient vertical

Microgravimetry measurement points taken inside Khufu's Pyramid. The measurement points concerned are (E) and (F).



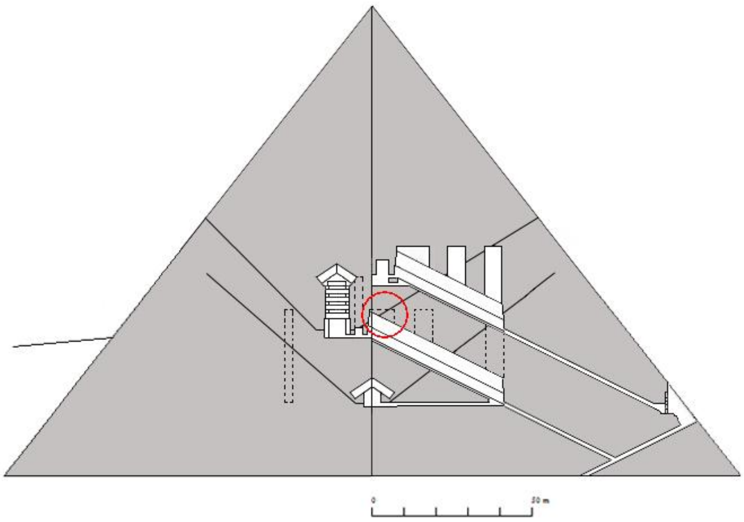
Les premières analyses du "coeur" divisé en 46 ensembles, confirment l'examen des valeurs résiduelles de premier ordre, c'est-à-dire qu'il existe là des hétérogénéïtés notables, modulant la densité moyenne du coeur évaluée à 2.02. La figure 8 montre en particulier:
- une zone lourde autour et sous la chambre des herses,
- une zone lourde au-dessus du milieu de la galerie de la Reine,
- deux zones légères au milieu et en haut de la grande galerie,
- deux zones légères, l'une en partie basse de la Chambre de la Reine, l'autre sous le milieu de la Chambre de la Reine (voir microsustructure),
- une zone légère possible à mi-chemin entre les chambres du Roi et de la Reine.

FIG. 8

Vue en coupe de la mésostructure
A : zones légères
B : zones lourdes
C : zone légère possible

The results in (E) and (F)[371] are marked A: light areas.
In particular, Figure 8 shows:
- Two light zones in the middle and at the top of the Grand Gallery.

[364] See footnote 318 Page 74
[365] To my father and I, after our meeting at the EDF Foundation in September of that year.
[366] The Engineering Geology of Ancient Works, Monuments and Historical Sites - Preservation and Protection. Extracts from the proceedings edited by A.A. Balkema / Rotterdam / Brookfield - 1988.
[367] Professor H.D. Bui, from Ecole Polytechnique: Laboratoire de Mécanique des Solides, was part of the team that processed the measurements collected during the mission.
[368] Organized by the Greek national group IAEG.
[369] It will be discussed in the document: "Khufu's Pyramid, recent discovery of a cavity under the northeastern edge by the ScanPyramids mission".
[370] Pages 1064 and 1068 of the Proceedings.
[371] This result will be discussed in the document: "Khufu's Pyramid, recent discovery of a corridor under the North face by the ScanPyramids mission".



In the present case, the result in (E) could confirm the presence of the GG1's upper well. Given its small volume, this could have been filled, either with sand (density 1.4 to 1.6[372]), either with limestone chips from quarries like in the mastabas[373] (density <1.7), and not with limestone blocks (density 2.1).

2 - Intermediate well of the GG1.

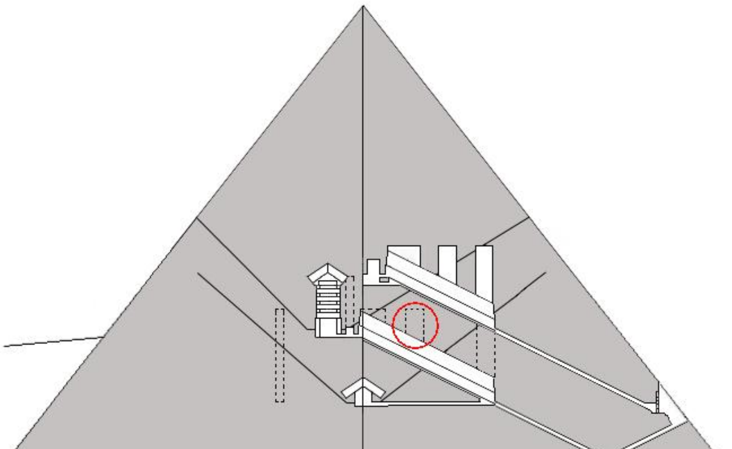
During my 5th stay[374] in Cairo, in November 2005, I noticed during a visit of the Great Pyramid a detail that intrigued me at once: the aspect of the limestone blocks of the Grand Gallery's cover was not uniform and traces of humidity and salt appeared on some blocks. I knew[375] that, following the looting of the Turah limestone façade and summit blocks, dew and rain water had been penetrating the body of the pyramid for several centuries, insinuating itself between the roughly hewn blocks on either side of the central socle on which the corridors, the Grand Gallery and the chambers were built. Most of the visible spots, small, were randomly distributed except in one particular area: around two thirds of the Grand Gallery, large semicircular halos centered on the roof betrayed a "channeled" water flow over several meters in length.

For me, this kind of detail was certainly not due to chance, but could be linked to a structural reason. During each visit, I took pictures of this part that intrigued me and during the ScanPyramids mission, I asked a member[376] to take new pictures[377] .

372 Loose sand and packed sand, also depending on its nature.
373 Like the filling of the structural caissons observable in the M17 mastaba at the foot of the Meidoum pyramid; a mixture of limestone cuttings and rudimentary mortar.
374 Between September 29, 2004 and May 8, 2010, I made eighteen visits to Cairo, for a total of about six months. I was thus able to make many visits of Khufu's Pyramid, without forgetting its consorts of Giza, Saqqarah, Dahshur, Abusir and Meidum.
375 Following the reading of Jean Kérisel's book: "Génie et démesure d'un Pharaon : Kheops" page 137.
376 Benoît Marini, designer of the muography simulation software.
377 A complete scan of the Grand Gallery was also made by students of the Faculty of Engineering in Cairo; this document is also in my possession.

On the left, photo from 2005, on the right, photo from 2017.
The successive semicircular aureoles are visible on several roof slabs, the first two being more marked than the following ones. On the photo on the right, the stains in the upper part are random.

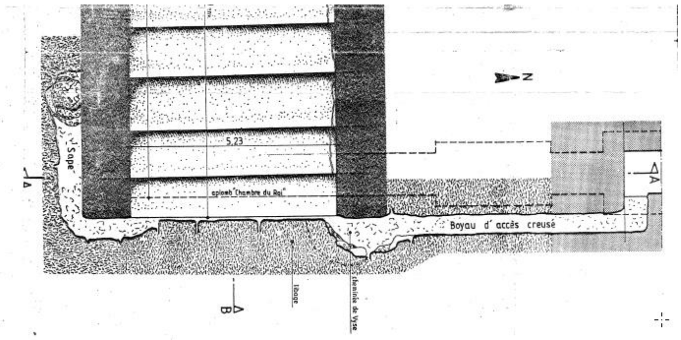
Following the discovery of the BIG VOID and my interpretation of it, it turns out that these spots are located directly below the intermediate well of the GG1, which was filled in before the construction of the GG2. I imagine that infiltration water could be "channeled" between the walls inside the well and concentrated in the lower part of the well, seeping between the joints of the cover blocks and eventually leaving these well-centered halos.
This phenomenon does not occur on the underside of the other two wells, the upper well being very short, the lower well being "protected" by the GG2 partly built in its upper part.



The red circle indicates the position of the semicircular spots on the underside of the GG1 cover.

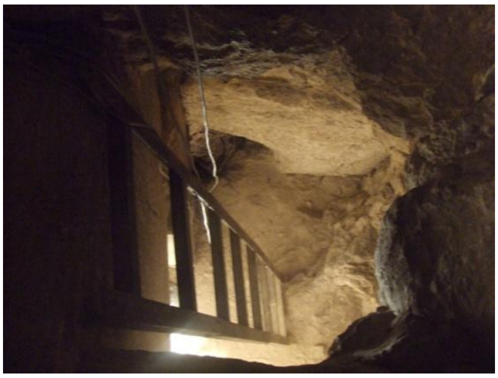
3 – Motor's well for the GG2 counterweight above the Portcullis Chamber.

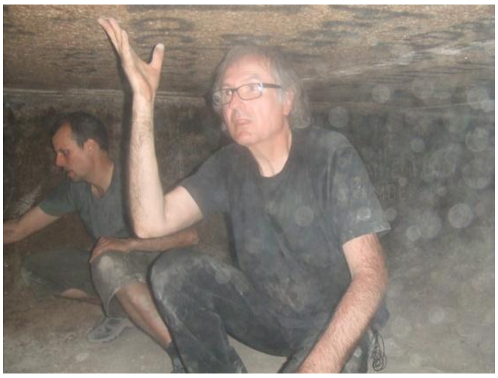
Following the cracking of the beams of the 1st ceiling above the King's Chamber that occurred before the end of the construction[378] of the pyramid, the architects had a small tunnel drilled[379] from the upper southeastern corner of the Grand Gallery directly to the northeastern corner of the superstructure above the Chamber.



Gilles Dormion plan.

The access tunnel runs from the top of the eastern wall of the GG1 to the 1st chamber above the King's Chamber in the northeastern corner.

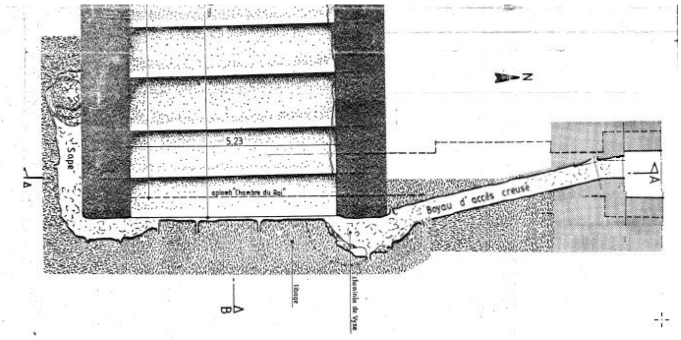




On the left, the exit of the tunnel coming from the Grand Gallery seen from the 1st so-called Davidson's chamber.
On the right, I am in the room with Benjamin Turquet[380] . I had the privilege to go up to the rafters of the roof and to see with my own eyes this astonishing structure and the numerous inscriptions left by the workmen of the time, among which the famous "Khufu's cartouche" (below).

[378] See document: *"A Computer Simulation to Determine When the Beams of the King's Chamber of the Great Pyramid Cracked"* By Richard Breitner, Jean-Pierre Houdin and Bob Brier – https://independant.academia.edu/JeanPierreHoudin.
[379] This is indisputable proof that these cracks occurred before the work was completed, as only the builders knew that there were voids above the Chamber.
[380] Photo taken in 2008 during the shooting of the documentary "Khufu Revealed" - See note 24 at the bottom of Page 34.

Until the discovery of the BIG VOID, I explained that the designers had chosen to drill this tunnel from the side to avoid "bumping into" the ends of the granite beams of the 1st ceiling, which would have happened if they had decided to dig directly from the top of the South wall of the Grand Gallery. I recognize that this explanation can be challenged because the workers could very well have dug at an angle from the top of the South wall and reached the northeastern corner.

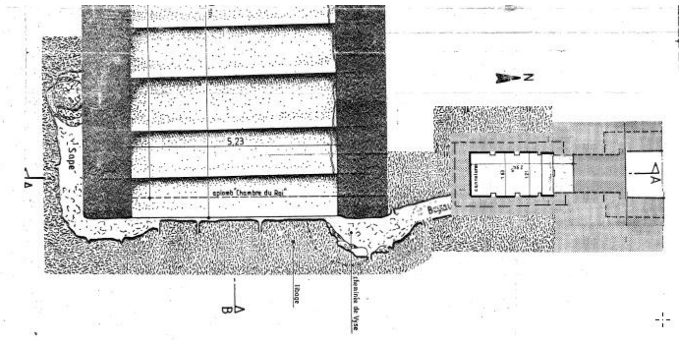


Based on a plan by Gilles Dormion.

Having personally crawled from the East wall of the GG1, I can testify that the entry, at right angle, into the tunnel is rather difficult and that the solution I propose above would have been much more practical for the workers; moreover, the tunnel would have been shorter, as well as the duration of the drilling.
The Egyptians must have been anxious to know what had happened above the King's Chamber.
It is therefore clear that an obstacle on this path has prevented the implementation of this solution.

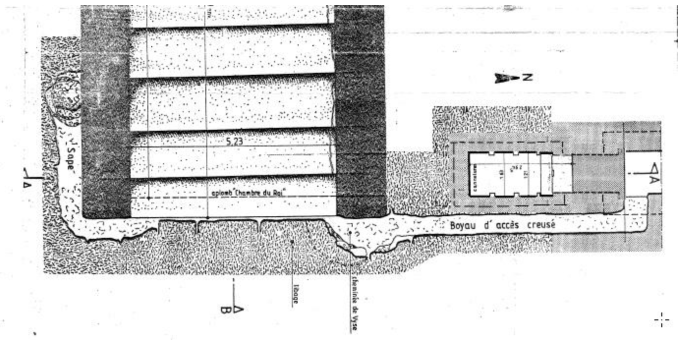
The discovery of the BIG VOID and my interpretation of it led me to imagine that the counterweight systems of the GG1 and the GG2 were supplemented by "motors" running in vertical wells; the one in the GG2 was built between the GG1 and the King's Chamber, above and extending the Portcullis Chamber.

At the end of the use of the GG2 counterweight, this well was filled, between the roof of the Portcullis Chamber and its outlet at level +64.10m, with backfill materials, therefore unstable masonry. Direct drilling was therefore impossible; the well would have had to be emptied to move forward.



Based on a plan by Gilles Dormion.

Drilling from the GG1 South wall was impossible because diggers would have to cross the GG2 backfilled motor well.



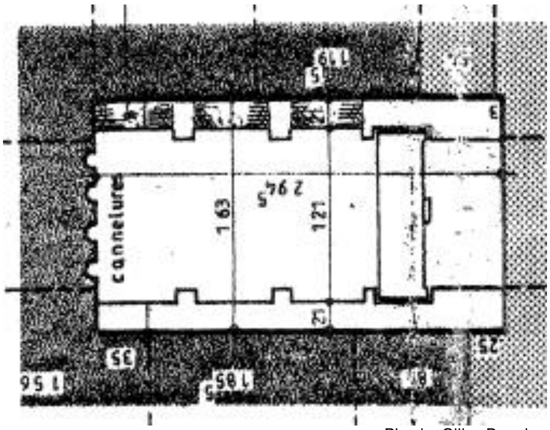
Based on a plan by Gilles Dormion.

The Egyptians were therefore forced to dig the entry to the tunnel in the East wall to avoid the GG2 backfilled motor well.

Moreover, an article[381] was published in May 1987[382] in the ANNALES of the “Institut Technique du Bâtiment et des Travaux Publics” following a work session which took place on October 23, 1986; the subject was "Aspects Techniques et Physique de l’Opération Khéops[383]”. In this article, Jacques Lakshmanan[384] and J.-C. Erling[385] write on page 121, Chapter 2, paragraph 2.5.1. "*Chambre du Roi et chambres de décharges*", about measurements made regarding a hypothetical unknown chamber located 8.5m north of the King's Chamber (translation):

"If we refer to the results obtained from the measurements (Fig. 18), we observe a number of anomalies much more dispersed. Their causes can only be much smaller than the simulated chamber and located at a very short distance. We can lean for the hypothesis of less compact zones or filling behind the granite slabs”.

Finally, to end with the motor well of the GG2, it is interesting to note the 1.63m wall-to-wall span[386] of the cover made of three granite blocks. Curiously, only the central block is crossed by a crack in the longitudinal axis of the chamber, this one being supported only on the lateral walls, the two others being supported on three walls. It thus seems that this cover is made up of slabs and not beams[387], a solution that would have been sufficient to support the twenty or so meters in height[388], or about 70 m3, of simple backfill in the well.

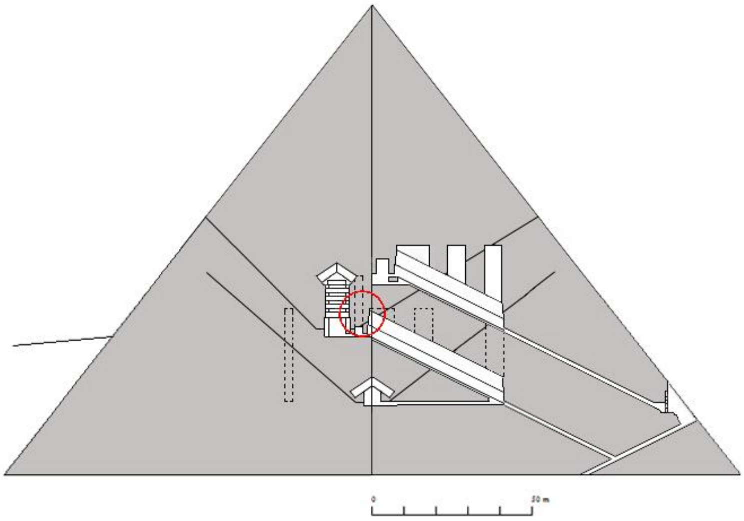


Plan by Gilles Dormion

© Mathias Glad

The span of the Portcullis Chamber cover slabs is 1.63m from wall to wall.
The width of the well above is identical to the width of the lower part of the Chamber, i.e. 1.21m.
A slight corbelling, of the same type as that of the modulation wells, was made for the setting of the slabs.

[381] La Prospection Microgravimétrique dans la Pyramide de Kheops, Pages 115 to 123.
[382] N°454 – Mai 1987, série : Architecture et Urbanisme 72.
[383] Following the microgravimetry mission carried out on Khufu's Pyramid under the EDF Foundation aegis.
[384] Geological engineer E.N.S.G. and Director of CPGF, the company which carried out the mission.
[385] Geophysicist engineer, Head of the gravimetry section at the same CPGF.
[386] From the East wall to the West wall.
[387] The difference between the two types is relative to their thickness, a slab being less thick than a beam.
[388] The well is covered in the upper part by the rafters of the North slope of the King's Chamber roof.



The red circle indicates an area where the Egyptians knew they could not dig the tunnel to check for damage to the granite beams of the ceiling of the King's Chamber.
The motor well of the GG2 counterweight system was located exactly in this area.

4 – Motor well for the GG1 counterweight south of the King’s Chamber.

Following the mission carried out in 1993 in the shafts of Khufu's Pyramid with the UPUAUT2 robot, Rudolph Gantenbrinck published a very interesting file on this subject on his website[389]. In the chapter devoted to the South shaft of the Queen's Chamber, the following details are specified:

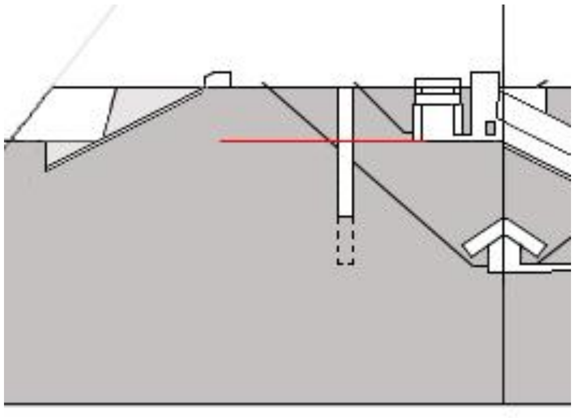
“Blocks No. 16 and 17 are offset by about 3 to 4 centimeters. It is impossible to determine with any certainty whether this deviation occurred during original construction or at a later date. This spot lies just under the floor level of the King's Chamber, where Petrie discovered unusual settling. (PETRIE, W.M.F., "Ten Years Digging in Egypt", New York, s.d.) It is possible that this settling and the observed deviations were caused by an earthquake during the pyramid's construction”.

In another document entitled “Additional measurements[390]”, he reports the position of the interior face of the East walls of the shafts in relation to the East wall of the Queen's Chamber; for the South shaft[391], this distance is 2.88m. Based on the dimensions of the GG2 motor well above the Portcullis Chamber, the interior face of the West wall of the GG1 motor well would be less than 1.80m from the East wall of the shaft; this support the idea that the blocks of the two structures would be contiguous.

In fact, Rudolph Gantenbrinck mentions the settlement of the South wall of the King's Chamber because it is a disorder which is located a little below the level of the ground of the latter and because it is the only work known in this South part of the pyramid. According to him, the shifting of these two blocks could be linked to this event. Only problem, the settlement of the floor of the King's Chamber is vertical (2 to 3 cm) while the shifting of the two blocks is lateral, from East to West; two unrelated disorders.

389 Unfortunately, this site has not been accessible for a few years. That said, at the time I had downloaded all the photos and written information, except for the drawings which were only accessible through software that is no longer available.
390 In addition to the description of the shafts.
391 Queens Chamber South Shaft 2.88 m* / Shaft width 21 cm Shaft height 21 cm (Opened by Dixon)

Finally, these blocks being embedded in the mass, extraordinary force to move them would have been required, causing an effect on the blocks upstream and downstream, which is not the case.



On the photo on the left, the shifting of blocks 16 and 17 of the South shaft of the Queen's Chamber. On the sketch on the right, the red line marks the floor level of the King's Chamber. Blocks 16 and 17 are exactly at the intersection of the shaft with the motor well of the GG1, *"just under the floor level of the King's Chamber"*.
The settlement of the floor of the King's Chamber is vertical (2 to 3 cm), the East-West shifting of the two blocks is lateral while the floor of the shaft remains continuous; there is no connection between these two events.

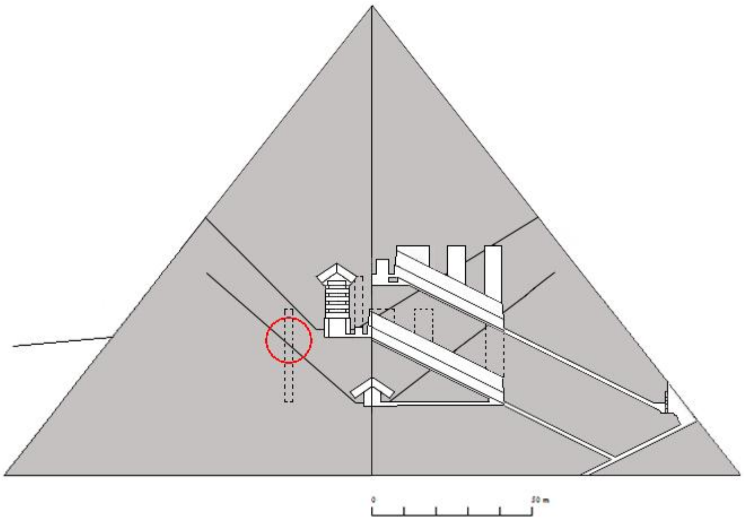
We must rather focus on the fact that these deviations date back to the time of construction. Thus, one must imagine that the South shafts of the two chambers had to progress along an axis very close to the ramp-slide of the monoliths in order to always be as close as possible to the transfer maneuvers. The starting point of the South shaft of the Queen's Chamber is nearly thirty meters from the crossing area with the motor well of the GG1, which starts vertically about forty meters below. Finally, all these Turah limestone blocks were “prepared” at the quarry, at the time of their extraction[392] and delivered on site ready to be laid.

The internal shifting of blocks 16 and 17 would therefore not be the consequence of an accidental event having pushed these blocks, but the result of a very small deviation in the progression of the shaft, leading to a misalignment of 3 to 4cm[393] of these blocks towards West. The site manager would have ordered to pursue the construction of the shaft, knowing that with a section of 21cm x 21cm[394], the 3 to 4cm of punctual shrinkage had no importance as for the use of the shaft; the transmission of acoustic waves!

On the other hand, the idea of a disorder occurring during an earthquake is to be totally excluded for a very simple reason: the pyramidal shape is essentially anti-seismic, a characteristic which was experienced by Pierre Delétie during the 1986 microgravimetric mission. During one of our meetings, he told me that one day, as he was in the relieving chambers, the Cairo area had been shaken by a rather strong earthquake which had worried his colleagues who were outside the pyramid at the same time. When he came out the pyramid, they rushed to him, relieved to see him again seemingly healthy. The first thing they asked him was, "*Weren't you scared up there during the earthquake?*"

He just replied: “*What earthquake?*”

[392] Like for the facing blocks to take advantage of the fact that the limestone was softer and therefore easier to work just after extraction; the more time passed, the more the formation of the cullet hardened it.
[393] Equal to two fingers (2 x 1.87cm) of misalignment in Egyptian measurements.
[394] The shaft of the King's Chamber are narrower, 18 and 21 cm in width and 14cm in height.



The red circle points out the area in which blocks 16 and 17 of the Queen's Chamber South shaft are offset by 3 to 4cm towards West; the East face of the shaft is less than 1.80m from the GG1 motor well.

5 – Careful fitting of the Turah limestone blocks of the South shaft of the Queen's Chamber.

In the same document mentioned above, Rudolph Gantenbrinck details at length blocks 26 to 28 which constitute the last section of the South shaft; I report the main points below:

“At the beginning of Block No. 26, a large section of the floor has broken away. This is the worst damage we observed anywhere in the shaft sequences so far investigated.

This highly unusual finding can have resulted only from one of two possible causes:

1 - Extremely inept construction work below Block No. 25 and 26. It must be remembered, however, that it is this final section of the shaft which otherwise displays the highest quality workmanship observed anywhere in the shafts system.

2 - The existence of an as yet undiscovered structure below or above this shaft section. Such a structure could produce a pressure peak, which could in turn focus considerable additional force on the shaft and possibly cause the observed damage.

At block No. 26, the shaft floor is marked by a long cutting groove. We found more such grooves in the floors of Blocks No. 27 and 28.

Cutting of precise joints using a copper bladed saw.

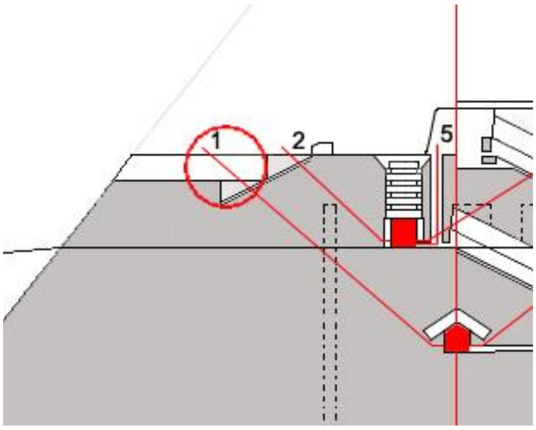
This method also leaves behind a cutting groove on the block underneath, a fact which testifies to the use of this method.

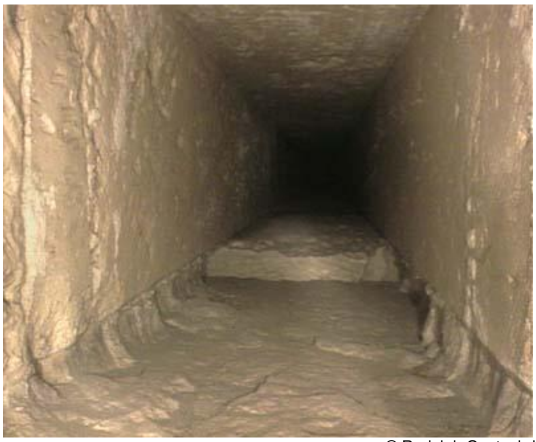
Based on the grooves found in the shaft, we can assume that, before their insertion as floor slabs, these blocks served as a base for the cutting of precision joints.

This gives rise to a crucial question: exactly which precision joints were cut here?

Taken together, these findings constitute a compelling case for a possible, as yet undiscovered structure - for which precision joints where made - in this upper region of the southern, Queen's Chamber shaft".

I have included all of this extremely instructive information with the following images. It is obvious that Rudolph Gantenbrinck could not imagine what I have been saying for more than twenty years, but the unknown structure that he foresees exists and it is linked, in my mind, to the construction process of the King's Chamber.





© Rudolph Gantenbrinck

On the left, in the red circle, the last section of the South shaft of the Queen's Chamber made of blocks 25 to 28. Block 25 is the block which makes the transition between the part of the shaft built in full mass and the last section which is built in the West wall which borders the ramp-slide for hoisting the monoliths. The visible gap between this block and the next is not the result of settlement but of an excavated floor, carried out for some reason by the workers on site; the joint with the side walls is in alignment in both blocks and the ceiling is in continuity.

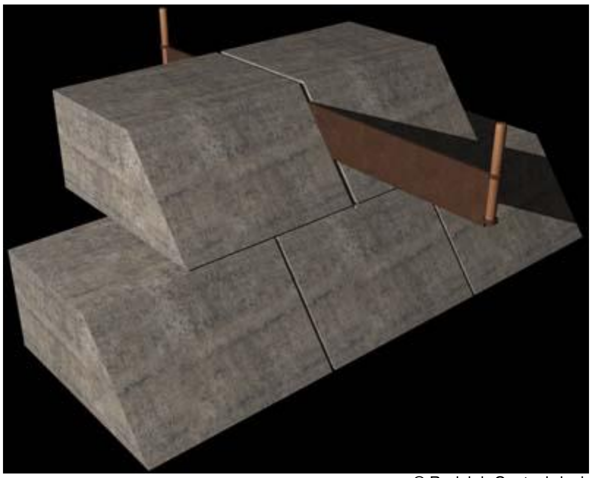
This is certainly not "*This is the worst damage we observed.*", nor "*inept construction work*" but rather an "on-the-spot catch-up" of a small problem as in the case of blocks 16 and 17.

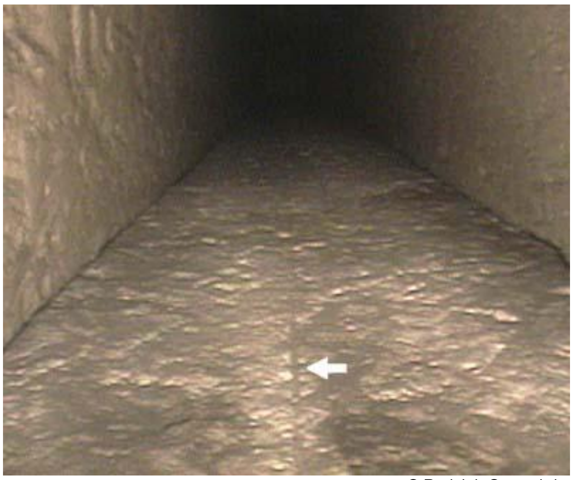
As for "*The existence of an as yet undiscovered structure below or above this shaft section*"; this structure is not where Rudolph Gantenbrinck imagines it to be, but less than one meter sixty from the shaft which must have been cut in blocks contiguous to those forming the western wall of the ramp-slide.

(illustration from the 2011 version)

The South shaft of the Queen's Chamber is as close as possible to the ramp-slide for hoisting the monoliths. It is part of the western wall of the trench built for this one, and it is highly probable that it was built on the spot as the wall was being constructed, which is of the same type as those of the Grand Gallery.

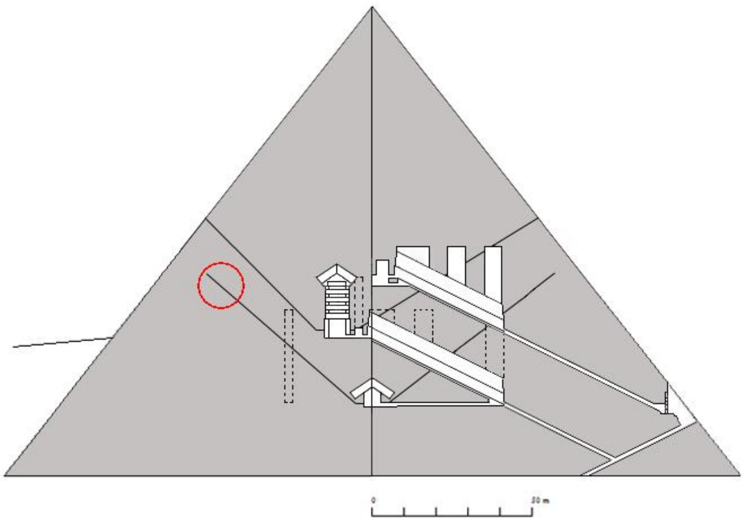
Rudolph Gantenbrinck nevertheless specifies: "*it is this final section of the shaft which otherwise displays the highest quality workmanship observed anywhere in the shafts system*".





On the left is an illustration in accompaniment of the sentence: "*Cutting of precise joints using a copper bladed saw*".
And on the right, these:
- "*At block No. 26, the shaft floor is marked by a long cutting groove. We found more such grooves in the floors of Blocks No. 27 and 28*",
- "*This method also leaves behind a cutting groove on the block underneath, a fact which testifies to the use of this method*".
- "*Based on the grooves found in the shaft, we can assume that, before their insertion as floor slabs, these blocks served as a base for the cutting of precision joints*".

All these details show a work of precision carried out on the spot because being difficult to realize upstream at the quarry. The memory of the incident that occurred at the intersection between this shaft and the motor well of the GG1 may have served as a lesson to the builders, these opting for a solution that would avoid repeating their past mistake: "custom made".



"Taken together, these findings constitute a compelling case for a possible, as yet undiscovered structure - for which precision joints where made - in this upper region of the southern, Queen's Chamber shaft".

The answer is simple: the ramp-slide for hoisting the monoliths of the King's Chamber is this unknown structure.

6 – The two “doors” at the end of the Queen’s Chamber shafts.

After Rudolph Gantenbrinck 1993 UPUAUT2 mission, a new mission, dubbed Pyramid Rover[395], took place in 2002. Its aim was to reach the "doors[396]" closing the shafts of the Queen's Chamber and to drill a hole in that of the South shaft to find out what was behind it. The mission itself was a success, a small camera was introduced by Pyramid Rover into the drilled hole, but surprise was considerable[397]: there was nothing in particular beyond the small door except a 14cm deep void closed by a block of raw limestone. On that side, it was a huge disappointment.

©Pyramid Rover

Closing slab of the South shaft.

©Pyramid Rover

Closing slab of the North shaft.

That said, since the camera could only film towards the front, speculation immediately began about what was on the other side of the metal pieces inserted into this South door.

So in the spring of 2009, I was contacted by Shaun Whitehead, a British engineer, who had seen a documentary about my work on the BBC. He was part of a team of university and private researchers who were preparing a new mission to explore the shafts of the Queen's Chamber with a miniaturized robot; this was carrying a camera[398] capable of filming on nearly 180°, so the faces behind the closing slabs. Lacking means[399] and interested by my journey in my research, he asked me for advice. Ultimately, after talking about with my friends from Dassault Systèmes[400], at the end of May 2009 I introduced them to Shaun Whitehead to study a possible collaboration on his project.

In the following weeks, an agreement was signed between Dassault Systèmes and the University of Leeds, the entity representing the mission project called “Robot Djedi”. For me, this agreement was very important because it subsequently allowed me to follow, from the outside, the work of this mission and to be informed in real time of its progress and the data[401] collected. Thus, I was aware of the discovery made on the back face of the South door before its public announcement.

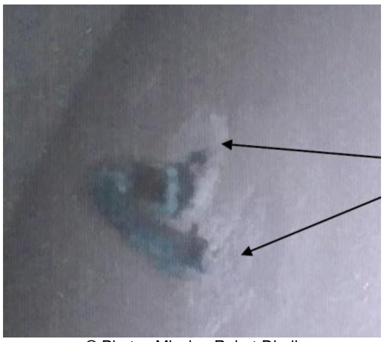
The two main discoveries of the mission were the copper loops in continuation of the needles visible on the front face of the slab, plus a line and signs drawn by the workers with hematite[402], the latter seeming to indicate a length of the shaft of 120 cubits[403]

[395] Led by Dr. Zahi Hawass with the support of the American television channel NatGeo.
[396] The word "door" has also been used in place of the words “closing slab” (or "closure stone") since the time of Rudolph Gantenbrinck's discovery.
[397] This event was broadcast live worldwide on the NatgGeo channel.
[398] Dubbed “snake camera”.
[399] At the 3D design software level and at the financial level.
[400] Mehdi Tayoubi and Richard Breitner.
[401] Like the 63.6m (at +/- 0.4m) length of the South shaft from its outlet in the Queen's Chamber to the closing slab (60mm).
[402] Red paint based on iron oxide used in large quantities by the Egyptians.
[403] Which seems consistent with the dimensions recorded by the Djedi robot – see note 400 above.

Left copper needle.

Right copper needle

Copper loop on the back of the left needle.



© Photos Mission Robot Djedi

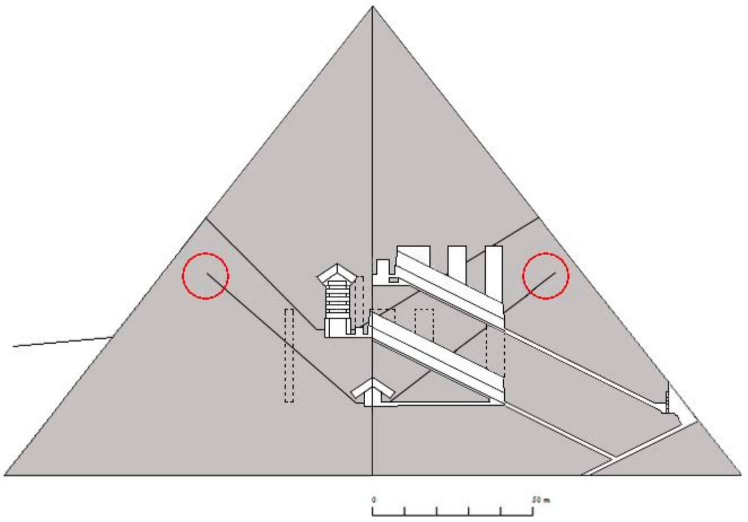
Copper loop on the back of the right needle

The presence of these two loops on the back of the closing slab clearly seems having an obvious link with a copper piece discovered by engineer Waynman Dixon in 1872 and which is now on display at the British Museum in London.

On the right, a double bronze hook with two holes meant for fixing it on a piece of wood like a tool handle.
This complete object would have been intended for the closing slab to be "taken out" of the shaft during the use of the intercom system and "set back in" at the end of its use to protect the shaft from rain, sand and animals or insects.
The dolerite ball on the left was also found in the shaft at the same time.

One must admit that it is astonishing that the discovery of this tool in 1872 occurred in a shaft that has been inviolate for nearly 45 centuries; and that in 2010 a robot discovered two copper loops on the back of a closure slab of a shaft that does not open anywhere today. However, this shaft was open to the outside throughout the construction of the King's Chamber and its superstructure before being permanently closed at the level where this work ended.

Finally, even if no mission has yet been able to explore what is behind the closing slab of the North shaft, it seems highly obvious that this part of the shaft must be identical to that discovered in the South shaft. The length of the North shaft and the presence of two copper needles on the closing slab, the "mirror-like"[404] of the South shaft, are proof of their common relationship in their function.



The South shaft of the Queen's Chamber is part of the intercom system and is sealed by a closing slab. This was removable and was used to protect the shaft when the counterweight system in the GG1 and then the GG2 was not in use.
This slab was laid in the shaft successively at levels +43.00m, +51.85m, +57.45m and +64.10m.
Its "closing slab" role ended at the level +64,10m when the construction of the King's Chamber was completed.

The North shaft of the Queen's Chamber mirrors the South shaft, and reaches the same level, after a sinuous course in its lower part to avoid "something"; it is sealed by the same type of closing slab

7 - Letters from engineer Waynman Dixon to George Reisner and Alan Rowe.

In December 2015, a few weeks after the beginning of the ScanPyramids mission, I was informed by one of my relations on social networks of the existence of letters[405] written by Waynman Dixon in 1925 to two Egyptologists of great renown: George Reisner[406] and Alan Rowe[407]. More than fifty years after the discovery of the shafts of the Queen's Chamber which he had made in 1872, Waynman Dixon, now an old man[408], certainly feeling the need to pass on a well-kept secret during all these years since his stay at the pyramids[409] in Egypt, had written a first letter addressed to the editor of the TIMES, published on January 20, 1924. In this letter, he was trying to arouse interest in a cheap scientific mission to uncover unknown structures inside Khufu's Pyramid.

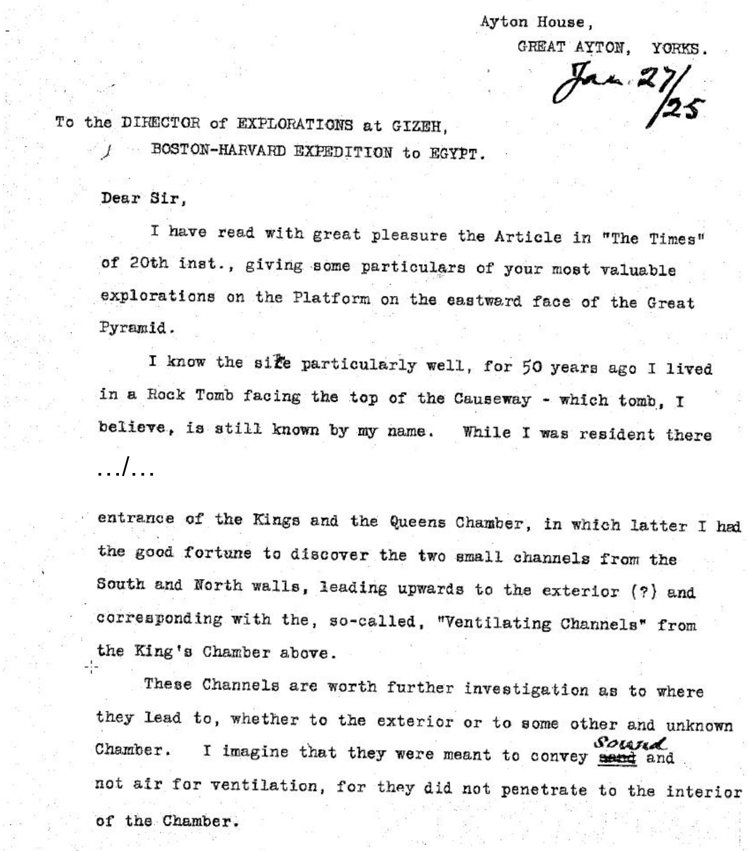
404 Even if the course of the North shaft is tortuous in its lower part, the level reached is identical.
405 In October 2021, I got in touch with Mrs. Maureen Melton, at the head of the Library and Archives of the Museum of Fine Arts (MFA) in Boston, who very kindly sent me a copy of all these documents. References are noted in the bibliography at the end of the document.
406 George Reisner was an American archaeologist, professor of Egyptology at Harvard, curator of the Egyptian collections at the Museum of Fine Arts (MFA) in Boston and, above all, director of the Harvard-MFA excavations in the largest concession on the Giza Plateau.
407 Alan Rowe was a British Egyptologist who is known for excavating the tomb of Queen Hetepheres on the Giza Plateau.
408 Dixon will die 5 years later at the age of 86.
409 Dixon had settled in a tomb near Khafre's Monumental Causeway in which the British Egyptologist Sir Flinders Petrie would later settle, in 1880.

Having had no response to this article, a year later, on January 27, 1925, he sent a four-page typed letter on the same subject to George Reisner, thinking that he was working on his excavations at Giza. Unfortunately for him, at that time Reisner was at Harvard and it was Alan Rowe who replied to him, telling that he could do nothing for him. Dixon will answer to Rowe to revive him but the epistolary exchange will stop there.

That said, in these letters, Waynman Dixon states that he knows where to drill holes to discover an unknown[410] circuit in the pyramid, asking only one thing in exchange: that once discovered, it be named "Dixon Passages".

Regarding the shafts of the Queen's Chamber, he wrote to George Reisner as follows:

"I had the good fortune to discover the two small channels from the South and North walls (?) and corresponding with the, so-called, "ventilating channels from the King's Chamber above.
These channels are worth further investigation as to where they lead to, whether to the exterior or to some other and unknown Chamber. I imagine that they were meant to convey sound[411] and not air for ventilation, for they did not penetrate to the interior of the Chamber"



Ayton House,
GREAT AYTON, YORKS.
Jan. 27/25

To the DIRECTOR of EXPLORATIONS at GIZEH,
BOSTON-HARVARD EXPEDITION to EGYPT.

Dear Sir,

I have read with great pleasure the Article in "The Times" of 20th inst., giving some particulars of your most valuable explorations on the Platform on the eastward face of the Great Pyramid.

I know the site particularly well, for 50 years ago I lived in a Rock Tomb facing the top of the Causeway - which tomb, I believe, is still known by my name. While I was resident there

.../...

entrance of the Kings and the Queens Chamber, in which latter I had the good fortune to discover the two small channels from the South and North walls, leading upwards to the exterior (?) and corresponding with the, so-called, "Ventilating Channels" from the King's Chamber above.

These Channels are worth further investigation as to where they lead to, whether to the exterior or to some other and unknown Chamber. I imagine that they were meant to convey ~~sand~~ Sound and not air for ventilation, for they did not penetrate to the interior of the Chamber.

Two excerpts from the first four-page letter from Waynman Dixon to George Reisner dated January 27, 1925

410 I will come back to this part at greater length in the upcoming document: "Khufu's Pyramid, recent discovery of a corridor under the North face by the ScanPyramids mission".

411 Strangely, Dixon corrected the typed letter which is in English by hand: he crossed out the word "sand" and wrote "sound". The person typing the letter must have had trouble hearing.

I take away two things from this excerpt:

1 – Waynman Dixon was an engineer[412] really interested in the construction and interior architecture of the pyramid and a supporter of scientific investigations.

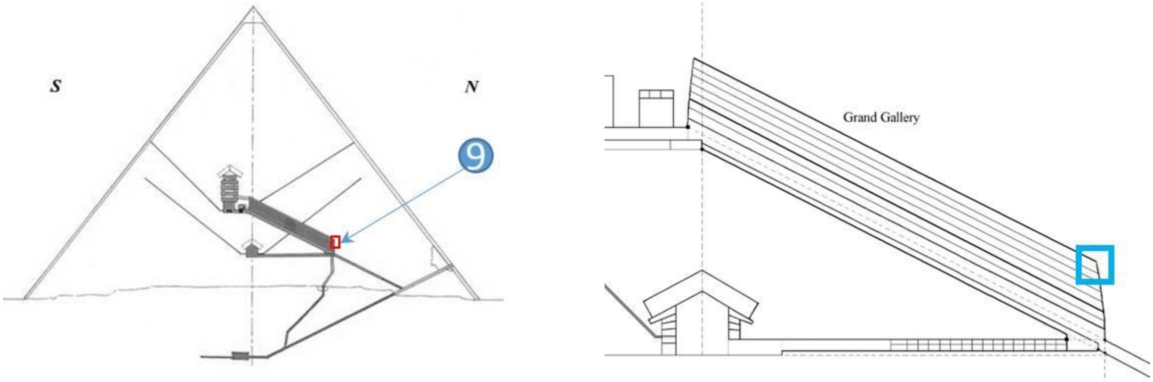
2 – He had perhaps had the occasion, certainly by chance, to live the experience[413] of the phonic communication between the outside and the King's Chamber by the North shaft of this room.

The fact that an engineer, who spent a lot of time in Khufu's Pyramid and who has studied it very deeply writes: "*I imagine that they were meant to convey sound*" must, in my opinion, be objectively considered as valuable information, in addition to the arguments made above based on precise details and events.

8 – Strange observation during the ScanPyramids mission.

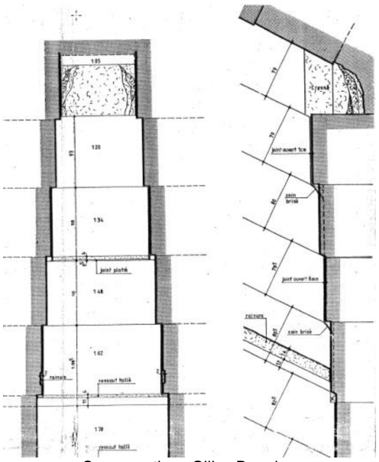
In the midst of a host of investigations undertaken during this mission, a number of anomalies that were identified by scientists working on site remained in the files, usually due to insufficient data or simply because they did not seem interesting enough to discuss publicly.

Thus, Jean-Claude Barré, a member of the infrared mission, had shared with me at the time about his astonishment regarding two temperature anomalies[414] that he had detected while taking measurements inside the pyramid. These were mentioned in a report prepared by the ScanPyramids mission in December 2015 entitled "*Thermal anomalies found on Giza and Dashur pyramids during first short Infrared mission, 1- 12 Nov 2015*" co-signed by Laval University in Quebec City and himself. Finally, several anomalies detected, including these, have not been made public.
That said these anomalies exists and should not be overlooked; thus the one of interest in the present case is linked to the North wall of the Grand Gallery, in its upper part, at the level of the cavity dug in the last block of this wall, apparently in the hope of discovering something behind it[415] .

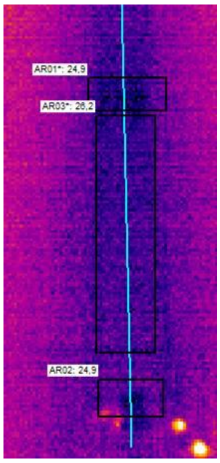


The infrared anomaly referenced No 9 in the December 2015 report was detected at the top of the GG1 North wall.

[412] He built several bridges between Cairo and Giza and transported Cleopatra's obelisk to London in 1877.
[413] Maybe with his brother who was also in Cairo at the time?
[414] The second will be discussed in the forthcoming document: "Khufu's Pyramid, recent discovery of a corridor under the North face by the ScanPyramids mission".
[415] Would there be a connection to the specific drilling locations Waynman Dixon mentions in his letter to Reisner?



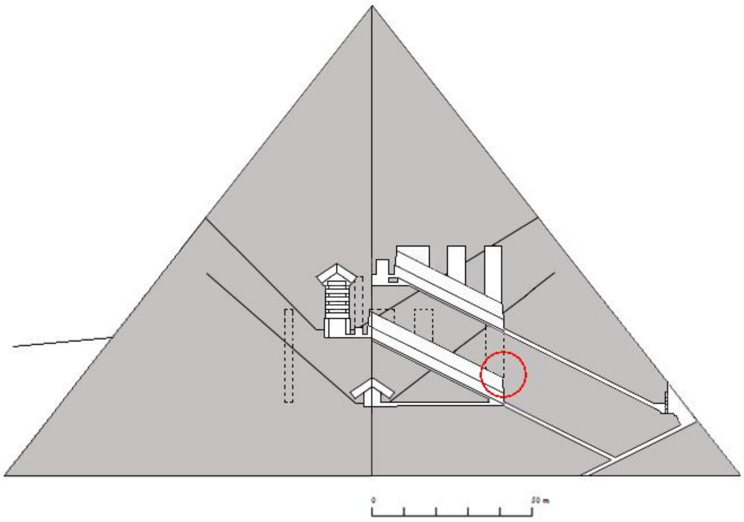
Cross-sections Gilles Dormion



On the left, cross-section and longitudinal section of the North wall of the GG1; in the center photo of the ceiling of the GG1 and on the right data recorded by the infrared camera.

The text about this anomaly mentioned:
"This infrared image corresponds to a view of the lower end of the Grand Gallery (the entrance, North side), which shows a behavior opposing what should be expected. Indeed, hot air is supposed to naturally go up. Hence, the temperature would normally be higher at the top than at the bottom. In addition the presence of a recess should further contribute to the accumulation of heat at the top. On the contrary, a colder zone can be seen".

An additional text followed providing clarification:
"The possibility that this temperature difference was related to rainwater infiltration was taken into account; that said the ceiling of Grand Gallery contains several traces of water infiltration and none of these has an effect on the temperature signature, the ceiling showing in fact an uniform temperature".



This anomaly is located in an area contiguous to the lower well of the GG1 and not far from the second ascending corridor connecting the NF-SPC corridor detected behind the rafters above the entrance on the North face and the GG2 North wall.

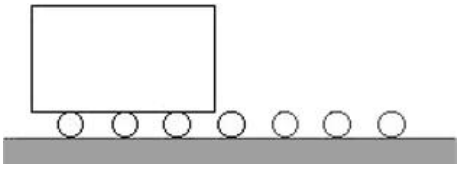
In the forthcoming document: « Khufu's Pyramid, recent discovery of a corridor under the North face by the ScanPyramids mission », the position of this anomaly will take on an unsuspected value.

9 – The safety system for the ballast-roller running in the ascending corridor.

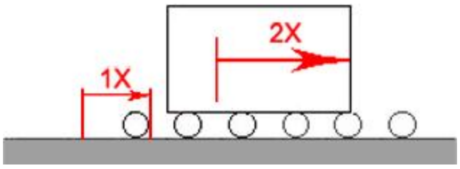
Important note about moving an object on rollers:

When an object is moved on rollers mounted on a fixed axis, that object advances at each turn of the roller by the equivalent of the perimeter of this roller; for example, for a 10 cm diameter roller, the object will advance by 31.4 cm (10 x 3.14).

On the other hand, when the rollers are placed on the ground, they will themselves move forward by 31.4 cm, which means that in total, the object will move by 62.8 cm, i.e. twice as much as the rollers.



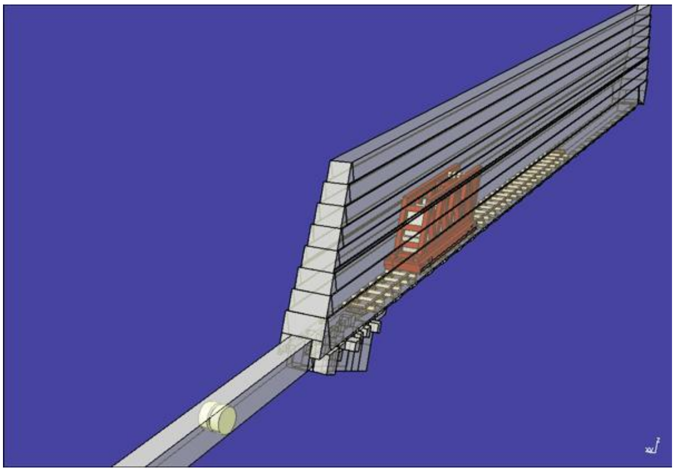
Object to be moved on rollers placed on the ground.



After the first full turn of the rollers, the object was moved twice as far as the distance covered by the rollers.

This detail is of great importance in the movement of the three counterweights set up in the construction site of the Great Pyramid, as these run on a rollers-train.

In Pages 12 and 13 of this document, I mention the introduction, starting in 2005, of the supposed use of a rollers-train inserted between the side benches of the Grand Gallery and the runners of the counterweight trolley for the movements. When hoisting the monoliths, this technique eliminated friction and thus contributed to a greater efficiency of the system.



In 2006, Dassault Systèmes engineers performed numerical simulations of the operation of the counterweight system, integrating a trolley moving on a rollers-train held in tension by a ballast-roller running in the ascending corridor.
The system worked perfectly without friction.

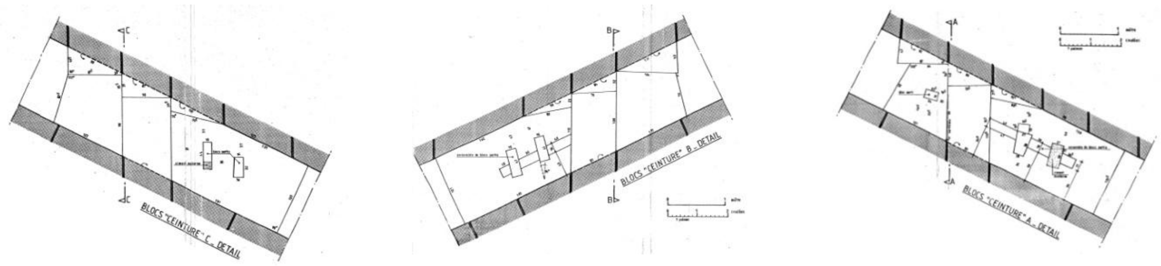
Two years earlier, having received[416] the complete set of plans of Khufu's Pyramid made by Gilles Dormion, I had been intrigued by particular details on the East and West walls of the ascending corridor[417]. For me, these had to do with the counterweight system I imagined inside the Grand Gallery; by introducing the rollers-train, with the necessity of maintaining it permanently in tension with a ballast-roller running in the ascending corridor, an additional element appeared obvious to me: to secure the tension system by minimizing the consequences of a break of the rope connecting the front of the rollers-train to the ballast-roller.

In the first paragraph on Page 13, I wrote:

The key to the movement of the counterweight trolley on the GG1 side benches is the installation of a rollers-train. During rearmament or restitution, the counterweight trolley moves[418] on this rollers-train, dragging it along. However, this train moves at half the speed of the trolley and is only about half the length of the GG1. To keep it permanently under tension, the front of the train is connected, by a rope making a U-turn on the platform at the top of the GG1, to a ballast-roller running in the upper part of the ascending corridor (which I have named "the cat's tail" by analogy).

At the time, due to the lack of available travel length for the counterweight, all calculations and explanations of the system operation were based on the principle of direct traction, as the GG1 was to deliver the monoliths from the five ceilings and the roof. The run length of the counterweight trolley and the opposite run length of the monolith hoisting platform were therefore identical, and this arrangement was compatible with the run length of the rollers-train and that of the ballast-roller.

Analyzing Gilles Dormion's plans, I noticed that the ascending corridor was made following two techniques:
- The first lower third of the corridor was roughly "dug" in horizontally[419] laid Turah limestone blocks, its section narrowing as it approaches its base. It therefore seems that the intention was to slow down, by funnel effect, the blocks at the end of their descent before blocking them in their present position.
- The other two thirds were built and well matched with blocks laid along the slope. Curiously, three "girdle blocks" were placed vertically at regular intervals (every 10 cubits from axis to axis) in the side walls. Behind these three blocks, the next three blocks are large and have vertical holes set in pairs (on two to the West and one to the East); the two downstream blocks also have a longitudinal groove parallel to the slope (one to the West and one to the East). All the holes have been filled very neatly.



Cross-sections by Gilles Dormion

Details of the three girdle blocks followed by large blocks with vertical holes dug in pairs.
On the left is the one upstream of the corridor in the West wall; in the center is the next in the East wall and on the right is the furthest downstream in the West wall. The three pairs of holes are spaced 10 cubits from axis to axis.
The two blocks downstream have also a longitudinal groove.

[416] I received these plans from Jean-Pierre Baron, with Gilles Dormion's agreement. The two men worked together during the 1986 microgravimetry mission, Jean-Pierre Baron being part of the CPGF team. In 2005/2006, the latter, who became director of Safège (formerly CPGF), was part of the mission prepared by the ACGP, the Faculty of Engineers of Cairo and the CNISF, with the microgravimetry technique.
[417] Plan N°7 – Couloir Ascendant.
[418] Simulations were also performed by Dassault Systèmes www.youtube.com/watch?v=xE39WfQRZL4 .
[419] To reconstruct a kind of artificial bedrock. Before becoming masons, the Egyptians were sappers, digging pits and galleries in the bedrock.

In the 2005 updated version of the counterweight system, I quoted that:

- All the holes in the most downstream block are at a distance from the GG1 equal to the maximum run of the "rollers-train", i.e. the use of the full length of the GG1, either for the ascent of the beams on the storage area at level + 43m, or for the last ceiling of the King's Chamber and the storage of the roof rafters at level + 60.15m.
- The set of holes in the other two blocks are respectively at a distance equivalent to the use of the counterweight for ceilings[420] 1 and 2, then for ceilings 3 and 4.

I concluded that wooden blocking wedges should be inserted in these holes depending on the level of use of the trolley, to serve as a stop in the event of the rope connecting the ballast-roller to the rollers-train broke. In the event of an accident and impact on a stop, the integrity of the ascending corridor was assured by the three girdle blocks and the three large blocks that follow.

The discovery of the BIG VOID and my conclusion that it is a second Grand Gallery that allowed the implementation of the 180° traction return technique reinforce and simplify the idea of safety stops. While the run lengths of the rollers-train and ballast-roller remains unchanged, those of the GG1 counterweight are affected: it can now only serve the first and the second ceiling due to the doubling of the length of the necessary traction ropes linked to this technique.

This change brings modifications compared to the 2005 version:

- The two downstream stops in the ascending corridor are each replaced by a long piece of wood beveled[421], inserted in the longitudinal groove and held in place by wedges inserted in the vertical holes. This arrangement creates a narrowing of the passage in the same spirit as the lower part of this corridor; the lower part of this “speed reducer” is thick enough to block the ballast-roller[422]. The furthest downstream device is permanent, with the counterweight used at the maximum[423] run length throughout Phase 1B and eighty-five percent of Phase 2A[424]. The intermediate[425] device is used only for hoisting the beams of the 1st ceiling in Phase 2A and for maintenance[426].

- The most upstream stop remains the same but its function is different: it is used to replace worn rollers with new ones stored in the horizontal corridor. To free up the access between this one and the GG1, the counterweight trolley is raised to the halfway position, allowing changes on the rollers-train upstream and downstream of the trolley. The latter is then lowered back to its basic position; the last rollers, those under the trolley during the maintenance operation, are changed. The run length of the rollers-train matches that of the first counterweight rearmament[427] with the monoliths hoisting platform. The distance covered by the rollers-train is identical to that of the ballast-roller between its initial position and the stop[428].

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420 During maneuvers for each pair of ceilings, the ballast-roller stopped about 1m from the stops for the first ceiling reached and about 3m for the second.

421 1.35m long on the East side and 1.60m on the West side.

422 A granite roller of Ø1.02m x 0.70m in length set in a wooden frame 1.37m long and 1.00m wide for a weight of 1.5t (according to an assembly proposed by Denis Denoël).

423 For a 19.79m run of the 1.37m long ballast-roller, i.e. a total of 21.16m. The start of the speed bump is at 21.27m (on the axis) from the outlet of the ascending corridor in GG1.

424 See Pages 101 to 103.

425 For a 13.06m run of the 1.37m long ballast-roller, i.e. a total of 14.43m. The start of the speed bump is at 15.83m (on the axis) from the outlet of the ascending corridor in GG1.

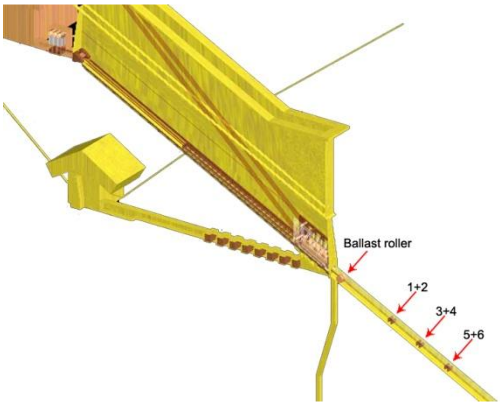
426 For additional security.

427 See Pages 71 and 72.

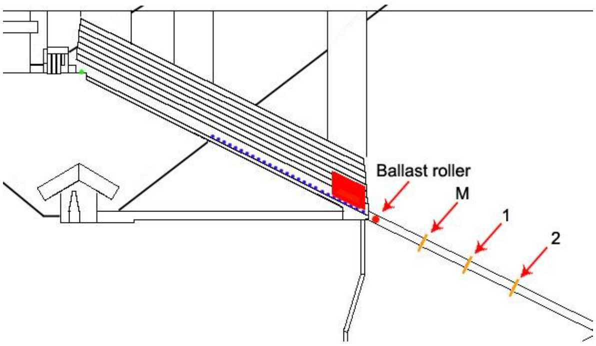
428 For a 9,89m run of the 1.37m long ballast-roller, i.e. a total of 11.26m. The start of the speed bump is at 11.26m (on the axis) from the outlet of the ascending corridor in GG1.

Safety system for the ballast-roller:
2005 version.

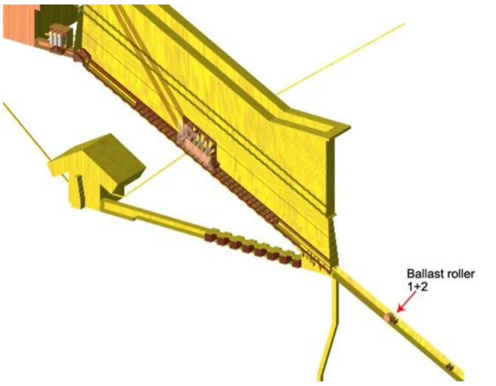
Safety system for the ballast-roller:
2022 version.



The counterweight system in the Grand Gallery in the 2005 updated version.
The three stops distributed along the ascending corridor ensured the safety of the system in the event of breakage of the rope connecting the rollers-train to its ballast-roller.
The numbers are for the ceilings affected by the stops.



The GG1 counterweight system during Phase 1B and Phase 2A following the update after the discovery of the BIG VOID.
The upper stop M is kept and used for maintenance and outside periods of monoliths hoisting.
The two downstream stops 1 and 2 are replaced by "speed bumps" for Phases 1B and 2A.



The upper stop secured the movements of the ballast-roller when hoisting the monoliths of ceilings 1 and 2. The ballast-roller stopped about 3m and 1m before the stop.
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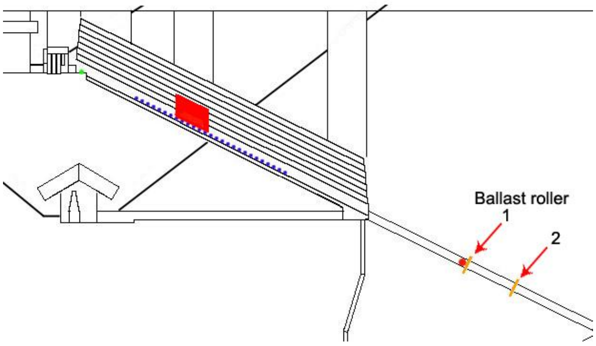
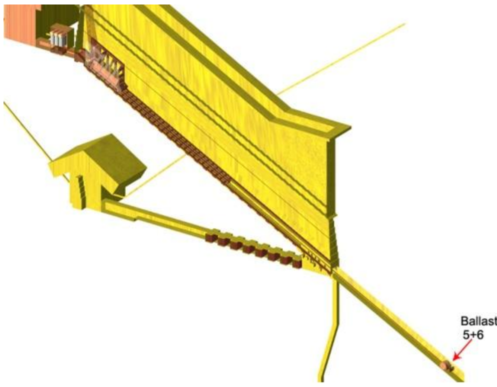
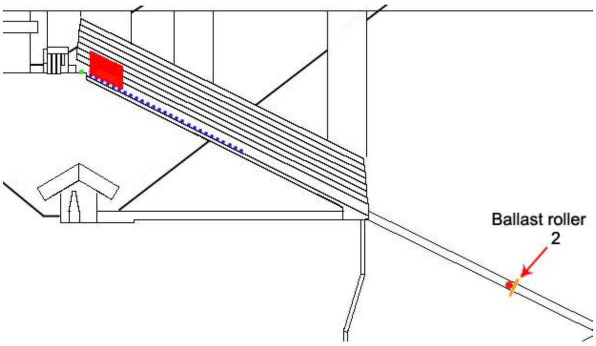


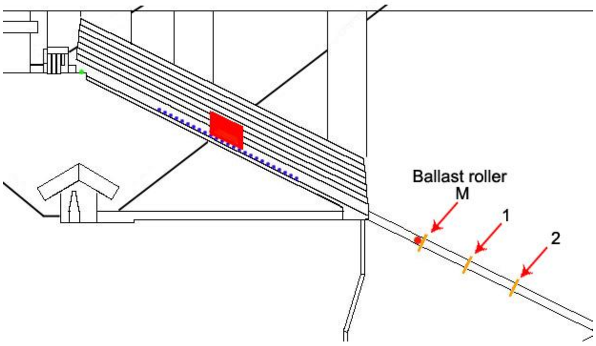
The ballast-roller stops less than 1.50m from the start of the intermediate speed bump for ceiling 1.
The lower speed bump stays in place for double safety.



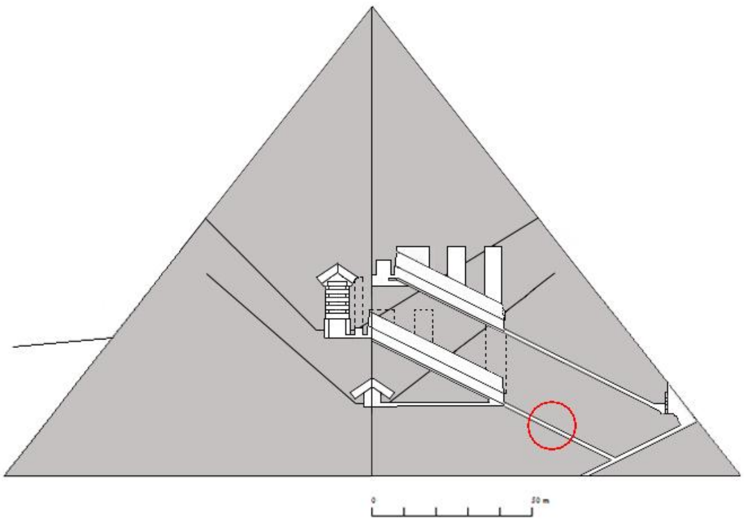
The lower stop secured the movements of the ballast-roller during the hoisting of the monoliths for the ceiling 5 and the roof. The ballast-roller stopped about 3m and 1m ahead of the stop. The intermediate stop was linked to ceilings 3 and 4.



The ballast-roller stops just at the start of the ceiling 2 speed bump. This configuration will be in effect for the full Phase 1B (approximately 520 cycles) and 85% of Phase 2A (56 cycles + as many counterweight rearmaments).



To change the rollers of the rollers-train, the counterweight trolley is lifted halfway up the GG1.
The ballast-roller comes into contact with the upper stop M. The two downstream speed bumps are in place.
The 10 cubits (5.24m) spacing from axis to axis between the pairs of holes in the side walls made the construction of the ascending corridor simpler: the upper and lower devices are respectively as close as possible to the end of the ballast-rollers run in both cases. For the intermediate device, the gap is less than 1.50m, thus very minimal.



It is obvious that the ascending corridor connecting the descending corridor to the Grand Gallery is not just a simple passage. It was made using two different techniques: one third of it was dug into a reconstituted bedrock base and the other two thirds were built on the upper part with a masonry that was very well designed in terms of block assembly.
Specific details show that it was also designed to meet specific needs related to a temporary activity taking place in its immediate environment, that is to say the Grand Gallery.

The function of the excavated part, with its narrowing in the last few meters, was to slow down the fall and then to stop the three granite blocks plugging its access from the Descending Corridor. These blocks had a role during the construction: to serve as the base load of a counterweight trolley used in the Grand Gallery to hoist the granite and Turah limestone monoliths of the King's Chamber and its superstructure.

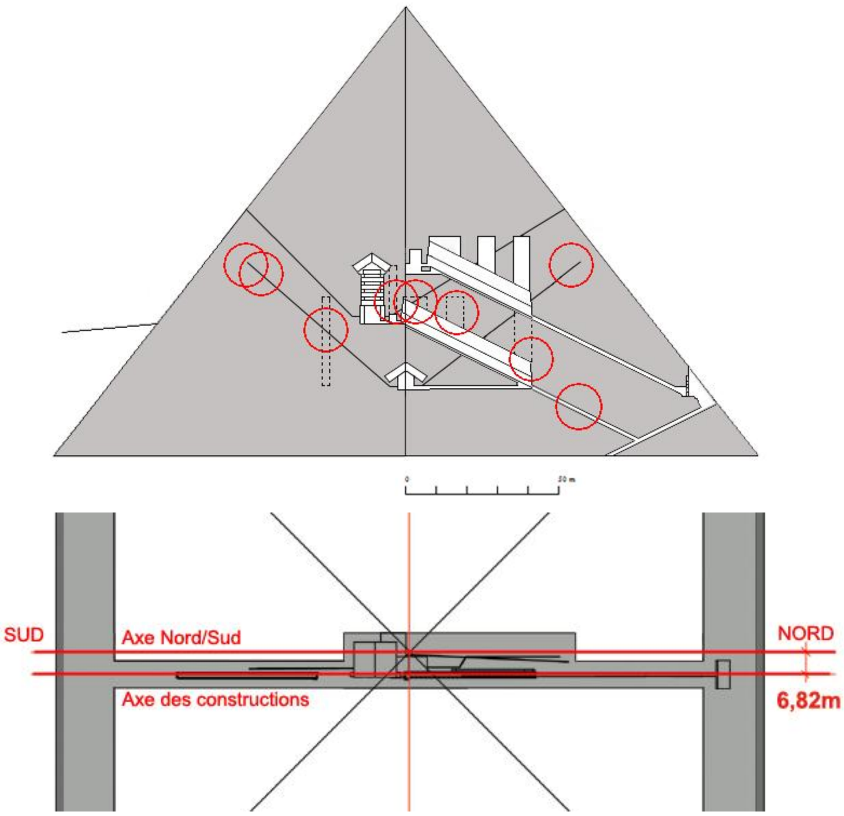
The function of the built part was to integrate a safety system for the ballast-roller linked to the rollers-train running in the Grand Gallery. Two emergency devices were provided in the event of a break in the rope connecting the rollers-train and the ballast-roller during Phases 1B and 2A, a third secured the maintenance maneuvers. At the end of the use of the Grand Gallery, the devices were removed and the holes in the side walls were carefully filled in.

10 – Observation following these clues with regard to the interior architecture of Khufu's Pyramid.

The most remarkable thing is the distribution of the circles surrounding the anomaly zones that are directly related to the global counterweight system based on the GG1 and the GG2; they are all aligned on the same axis from North to South, the axis concentrating all the known corridors, the Grand Gallery and the Queen's and King's Chambers. This axis was deliberately shifted 13 cubits[429] to the East of the North-South axis of the pyramid because the latter had to be permanently free of any obstacle; this in order to serve as a construction reference throughout construction site, whether that of the volume itself or for the interior structures, particularly the King's Chamber and its superstructure.

The orientation of the pyramid, aligned with the four cardinal points, was primarily symbolic in relation to the belief in Eternity and the cycle of day and night. However, as always in Egyptian practice, it also had another temporary function, that of being an immutable reference on which the builders could rely during the entirety of the work: an axis that could be constantly checked and recreated at any time.

The solution came from the observation of the stars, the North Star to be precise, which allowed them to have this North-South axis that crossed the pyramid from the base to the top.



All the circles are aligned along the same axis running from North to South. This axis concentrates all the known corridors, the Grand Gallery and the Queen's and King's Chambers, and is offset 6.82m to the east of the North-South reference axis.
On the lower plan, apart from the shaded areas, made of Turah limestone, the pyramid is only made up to the 120th layer[430] of a filling of rough local limestone blocks, cuttings and coarse mortar in which no work has been built there.
Beyond, it is made of blocks of Turah limestone and local limestone well dressed.

[429] That is to say 6.82m from the North-South axis, a measurement verified by Rudolph Gantenbrinck in 1993.
[430] I.e. up to the level +90,00m.

13 – CONCLUSION ABOUT THE BIG VOID DISCOVERY.

As soon as I became interested in Khufu's Pyramid, almost 25 years ago now, I thought that anyone who wanted to explain its construction should rely on the following basic paradigm:

“The problem of the construction of the pyramid must never be reduced to the question of the volume alone; this is the fundamental error of all the theories proposed since the dawn of time. The most extraordinary building site is that of the construction of the King's Chamber in the heart of the volume of the pyramid. Without an explanation about this building site, the enigma of the construction of Khufu's Pyramid can never be solved”.

This is why I wrote in the 4th paragraph, Page 2, of the PREAMBLE:

“In March 2001, I was already fully convinced that the architects had imagined the project designing two distinct building sites integrated one into the other: on the one hand the volume itself, on the other the King's Chamber and its superstructure; these had then been realized with completely different methods and means, each one being optimized for a perfect execution”.

I continued in the 2nd paragraph of Page 3:

“Last element very important to understand my state of mind in my work on the pyramid: I always tried to make my proposals evolve, as I progressed, with the focus on "logic and simplicity", which for me were fundamental in the design and construction of the Great Pyramid”.

To add, in the 3rd paragraph of Page 7 about the ScanPyramids mission:

“Being part of this project in the background and due to the amount of data that has been accumulated during the course of the project, I have acquired a great deal of knowledge of the file and I feel that it is perfectly legitimate for me to speak about the discoveries announced by ScanPyramids and to give my interpretation of the Big Void on a very solid basis”.

I believe that I have, throughout this very long document, provided precise, detailed and credible answers to all the questions raised by a construction site that relies on the concept of a counterweight system as the only possibility for its implementation. Since the beginning of the development of this idea, in early 2001, I always tried simplifying the process and, on the other hand, to look for clues on site.

At the end of 2004, the first clues, found inside the Grand Gallery, began to support my proposals.

In 2010, the discovery on the Giza Plateau of new evidence converging on the probable use of a second counterweight system for hoisting the monoliths from the delivery port to the base of the pyramid external construction ramp supported these proposals.

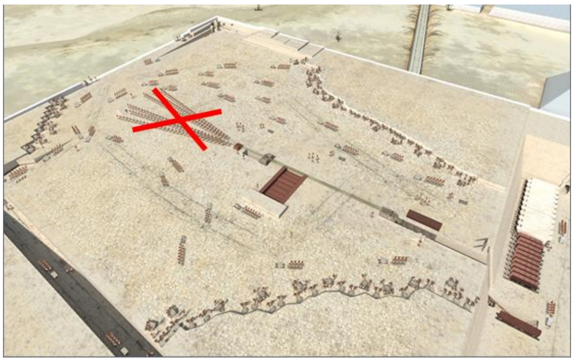
At the same time, the use of counterweights was gradually simplified, but unfortunately limited in effectiveness by the length, too short, of the Grand Gallery, forcing the use of human force in mass[431] during the construction of the superstructure above the King's Chamber.

[431] The hoisting of the monoliths towards their destination ceiling implied the use of about two hundred men for the heaviest ones, which did not seem to correspond to the logic that animated the mind of the Egyptians of the time.

On November 22, 2016, during a ScanPyramids mission work session I was attending, the discovery of a "Cavity" was announced by the Japanese team of Nagoya; looking at its position and estimated size, I immediately told the audience that this cavity was a second Grand Gallery.

Since that day, all the obstacles preventing any simplification of the hoisting of the monoliths by the use of counterweights have been removed and logic has prevailed throughout the journey of their transport; massive human force has become unnecessary. Otherwise, reduced human force was still used but only for specific tasks such as the modulation of the loads of the counterweights.

In my 2018 New Year's greeting, just two months after the official announcement of the discovery of the BIG VOID in *Nature* magazine, I illustrated my card with the image below accompanied by the text that follows it:



Direct consequence on my theory after the discovery of the "BIG VOID" by the ScanPyramids mission: 200 unemployed. (A second counterweight in a second Grand Gallery at the heart of the pyramid removes any extra human force for hoisting the beams of ceilings 3, 4, 5 and the roof rafters above the King's Chamber).

I was able to announce this update because I had been working on this discovery for over a year already, being close to the mission without officially participating in it.

Later, in January 2021, in an interview[432] I said:

" - The BIG VOID is a second Grand Gallery having housed a counterweight (in fact the first reused) which took over from the first for the hoisting of the beams and rafters beyond the second ceiling later in the course of the construction. The idea of a second counterweight means that there was no more the need for any complementary human pulling team as I said previously. Like the shafts of the Queen's Chamber, those of the King's Chamber have also been part of the sound communication system, connecting the northern part to the southern part of the pyramid during the use of the second counterweight.

All these new major updates are now superbly detailed and scientifically backed with the help of engineers. Stored in several hard drives, they will become public one day if certain conditions are met".

Finally, at the end of summer 2021:

"I decided to start writing my interpretations of the three major discoveries of ScanPyramids, starting with the BIG VOID, as this was the key to the reconstruction of the most technically impressive part of the pyramid, the King's Chamber and its superstructure"[433].

[432] Interview by Sharon Janet Hague for the series "Stars of Egyptology" published on her blog www.sharonjanethague.com.

[433] See Paragraph 3 Page 50

The most extraordinary thing is that during these twelve months of work and writing, the enormous amount of information I had stored, both in my brain and in my computer, allowed me to go even further in simplicity and logic than I ever imagined at the beginning of my research.

On March 1, 2004, I had a meeting with the managers[434] of the company EIFFEL Construction Métallique[435] to present my work in view of a possible sponsorship[436].

The next day I received an email from Marc Buonomo[437] (AM engineer) - (excerpts translated):

"I think that you will be at the origin of a discovery superior to that of the discovery of the tomb of TUTANKHAMUN.
…/…
I'm interested in your study because you show that it was engineers and scientists who did this work. One will have to wait for Leonardo da Vinci to find again the scientific spirit. As such, if your theory proves to be correct, you will have overturned everything we think about the Renaissance and its engineers.

When I look back at the course and evolution of my theory, I say to myself that at the time, neither he nor I could imagine the degree of knowledge and know-how reached by the designers and builders of Khufu's Pyramid.

In Page 3, I wrote:

"I am absolutely convinced that Hemiunu and Ankh-haf, the architects-engineers who designed and built the Great Pyramid, were geniuses".

I'm even more convinced of that now.

Hemiunu

Ankh-haf

As for me, I am only deciphering an extraordinary 4.500 years old architectural know-how.

"All men owe gratitude to those who study universal history and strive to contribute, through their work, to the general good of society".

Diodorus of Sicily - Historical Library - Book 1 - 1st century BC

To be continued…

434 Jacques Huillard, the President, and Marc Buonomo, the Director of the group's factory in Lauterbourg. At the time, this company was building the Millau Viaduct; all the metal elements, deck and cable-stayed pylons, were prefabricated in Lauterbourg and transferred by special convoy to the viaduct site.
435 Which became EIFFAGE in the meantime.
436 The EIFFEL Company had subsequently become one of the most important sponsors of the ACGP, supporting many of my trips to Cairo.
437 At the time Marc Buonomo told me that the technique for raising the metal pylons of the viaduct was inspired from that used by the Ancient Egyptians for their obelisks, by playing on the center of gravity.

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HAL Id: hal-01630260
https://hal.inria.fr/hal-01630260v2
Submitted on 22 Nov 2017

DISCOVERY OF A BIG VOID IN KHUFU'S PYRAMID BY OBSERVATION OF COSMIC-RAY MUONS
Kunihiro Morishima, Mitsuaki Kuno, Akira Nishio, Nobuko Kitagawa, Yuta Manabe, Masaki Moto, Fumihiko Takasaki, Hirofumi Fujii, Kotaro Satoh, Hideyo Kodama, et al.
Corresponding Authors: Kunihiro Morishima and Mehdi Tayoubi

For the final, post-review version, please see:
http://www.nature.com/nature/journal/vaap/ncurrent/full/nature24647.html

15 – USEFUL INTERNET LINKS TO DISCOVER MY WORK

SITE INTERNET DE L'ACGP

Association Construire la Grande Pyramide, crée en 2003 pour soutenir mes travaux de recherche sur la Grande Pyramide
https://www.construire-la-grande-pyramide.org

PYRAMIDALES, blog by Marc CHARTIER, journalist

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