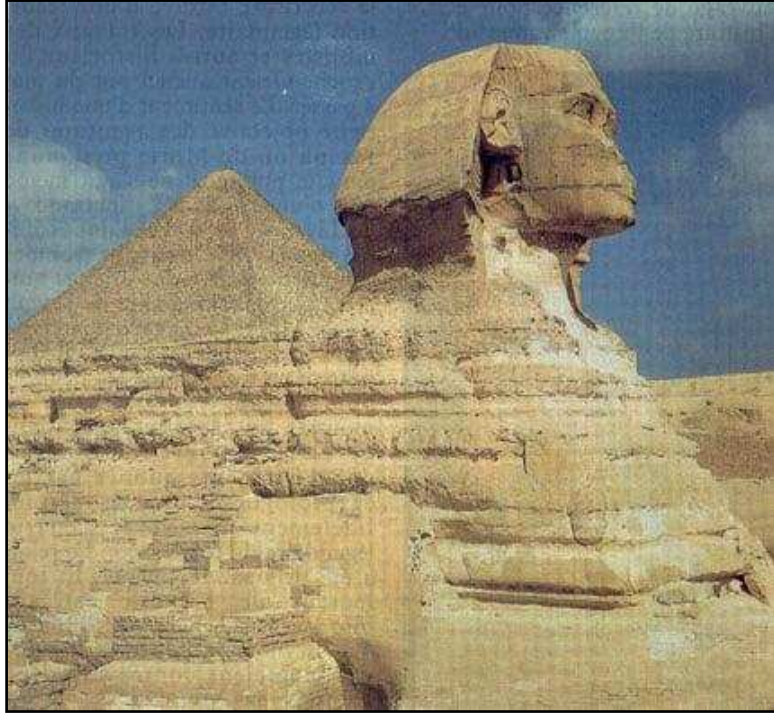


Pierre CROZAT, ©  
Architect-Town Planner EPF-L (1971)  
Dr. Engineer INPL/ENSMN (2002)



« SYSTÈME CONSTRUCTIF DES PYRAMIDES »  
1997-ISBN - 2-88382-065-1

## ENGINEERING OF THE PYRAMIDS

« LE GÉNIE DES PYRAMIDES »  
(2002- ISBN - 2-84454-161-5)

## DIGEST

F – 39380 LA LOYE, 2017  
pierre.crozat@free.fr

# Contents

ABSTRACT.....	3
PRELIMINARY STUDIES - EPF-L (Switzerland) (1994-1997)	4
• A SCIENTIFIC, TECHNICAL and OPERATIVE RESEARCH .....	6
• THE PROCESS OF "PYRAMIDAL GROWTH" .....	7
DOCTORAL THESIS - INPL / ENSMN / Laego / Civil Engineering - 1999-2002	13
• "GEOLOGICAL HYPOTHESIS" Development: .....	15
• TECHNICAL CONTINUUM of TUMULAR WORKS .....	18
POSTDOCTORAL STUDIES (2003-2015)	21
3D SIMULATION of the "Paleo-Topo-Stratigraphy" of the GIZA PLATEAU	24
PUBLIC CONFERENCE at the Documentation Center for Cultural and Natural Heritage - CULTNAT at Smart Village, Cairo - Egypt:	27
THE SCANPYRAMIDS PROJECT (02/11/2017)	28
OPEN LETTER: my interpretation of the possible "great void" in the Cheopspyramid ( <i>facsimile of the original email</i> )	28
GENERAL CONCLUSION: the engineering of the pyramids	30
NOTES	32

## Illustrations

Figure 1: Ramps suggested in "ramp" theories.....	4
Figure 2 : Possibles machines proposées dans les théories machinistes.....	5
Figure 3 : frontal ramp simulation in situ.....	5
Figure 4: lever arm on tripod suggested by J.P. Adam, if the principle and the scale seem accurate, the counter-weight could be "living" workers used as dead weight! .....	5
Figure 5: The three great smooth pyramids of the Giza plateau are located at the centre of the quarries where the material of the pyramids comes from .....	6
Figure 6: Reconstruction of the Giza area, suggested by G. Goyon.....	7
Figure 7: To lift and to lay a block onto two other blocks makes up an algorithm.....	8
Figure 8: modeling at scale 1/10 and at scale 1/3 .....	8
Figure 9: modeling of the "pyramidal growth" process, by successive envelopes, from an elementary [4+1] little pyramid at the centre of the base, side by side, block by block according to the algorithm ..	8
Figure 10: by anticipation of the construction on one side, inclined plans can be built and a corridor, a room that will end up inside the pyramid, after the building of the four sides is complete .....	9
Figure 11: the inclined plans allow the positioning, through sliding, of the monoliths.....	10
Figure 12: an "extraordinary oblique lift", with rack, counter-weight (pad-blocks) .....	10
Figure 13: layout of the blocks on the S.W. edge and on the top (notice the notches).....	11
Figure 14: optical restitution of the leveled top of Cheops and interpretation: a color for each side by the author .....	12
Figure 15: Mykerinos, last granite "cleaned" envelope .....	12
Figure 16: Diagram of the relationship between the successive quarries and the successive envelopes built on the basis of a double surface quarry of that of the pyramid, in section (hypothesis stated since 1997). .....	13
Figure 17: remains of the quarries at the foot of Chephren, and at the N.W. corner of Mykerinos (covered in sand).....	13
Figure 18: Theoretical scheme of distribution of natural fracturing networks of rocks. ....	14
Figure 19: schema of the system of the natural double fracturing of the rock on the Giza plateau (hypothesis to develop and verify in situ). .....	15
Figure 20: Synthetic table of the structural and stratigraphic geology of the Giza plateau. ....	17
Figure 21: Aerial shot of Cheops' "temenos", showing the quarry exploitation of the blocks according to the secondary fracturing (diagonal to the axis of the fold).....	18
Figure 22 : Tumulus - Tomb Maeshowe (Cyclades) and Dolmen de la Joselière in Pornic (France)....	19
Figure 23: Cairn in Barnenez (religious engineering), threshing area in Cipierre (rural engineering) ..	19
Figure 24: accretion-raising" system applied to any step-pyramid (like Saqqara) (by P. Crozat and G. Agonès) .....	19
Figure 25: Comparative diagrams of the mode of construction of step pyramids: .....	20
Figure 26: Explanatory panel of the pyramid construction phases (in model).....	21
Figure 27: Discovery of tectoglyphs on the base of Chephren (R. Perrier & P. Crozat - 2005).....	22
Figure 28: Peak Manufacturing and Extraction Surgical Trials – Dismantling. ....	22
Figure 29: Superposition of orthophotoplan and satellite photography.....	23
Figure 30: 2D cross sections on the diagonal of the 3 pyramids of Giza.....	24
Figure 31: Section on Chephren's Rising Alley showing that the Upper and Lower Temple and the Sphinx's head belong to the Auversian layer (7 ' ) a) hard limestone to small Nummulites & Curvispira .....	26
Figure 32 : Coupe sur le Mastaba de Khent-Kawes .....	26
Figure 33: Cup on the Sphinx: his head is Auversien.....	27
Figure 34: Cheops' pyramid by night (J. Kérisel) showing the thickness (shadow on the edge) of the envelope?.....	31

## ABSTRACT.....

Since the time they were erected, nearly 5000 years ago, the manner of construction of Egyptian Pyramids still remains an enigma that contemporary technologies are unable to solve. The theories that have been put forward until now by various authors are contradictory and cannot satisfy entirely the practitioner of the Art of building. None of them has ever offered a truly scientific, technical and operative approach, nor any element of convincing evidence.

A builder by training, during a family trip in 1990 I gave myself a challenge on the Giza Plateau: "If I had to build a pyramid, how would I do it?"

In this article, I investigate the case of the Great Pyramids of the IVth dynasty, mainly the three Pyramids of Giza. I focus in particular on Cheops', the most enigmatic because of its internal design, but actually and paradoxically the most revealing of the Pyramids' constructive system presented here<sup>1</sup>. This work was completed by research: thesis, postdoctoral studies, etc.

Preliminary studies (1992-96): I had an intuition about vernacular buildings while looking at the Sphinx, and decided to pursue this avenue by enrolling in a doctoral thesis in Architecture at the EPF-L with my former Prof. F. Aubry, specialist in "vernacular construction".

By contrast with many authors, I do not consider that the stones used to build the pyramids came from "very far away in Arabia"; similarly, I do not think that the building process was achieved with the help of "levees needed to haul the blocks", as reported by Diodorus of Sicily. I think that the stones came directly from the plateau of Giza's and that the builders used a method of construction defined as "pyramidal growth".

In this text, I propose a building technique based on practical necessities such as: 1. the search for the necessary materials which in turn defines a rational choice for the implantation, 2. the use of a constructive method which implies a labor organization and 3. the provision of all material supplies. These questions have their answers within the different disciplines contributing to the Art of building.

There is a precise set of rules for the pyramidal constructive method. The first principle: "to make use of the surrounding stone and to stack it up into the centre"; the operative algorithm: "to lay a block on two others with an overhang in an additive and recurrent manner"; the constructive system: "block by block, side by side, by successive layers" defining in this way the "pyramidal growth". As a consequence, the pyramidal growth is a necessary function of available techniques and of the dimensional characteristics of the building materials. Moreover, the building blocks and the general array of the exploitation sites are direct consequences of the natural geological features and of the fault patterns commanded by tectonics.

This constructive system can be modeled in order to investigate its consequences. It leads necessarily to "pyramid-shaped" constructions without the need for sophisticated conceptual plans. The shape of the pyramids and its angle is a direct function of the algorithm defined by the local array. Moreover, the method leads also to a natural interpretation of the devices found inside the Pyramid of Cheops. The internal gallery system can be created by anticipation of the construction method of one face of the pyramid, with an inclination angle matching the real one. Also the Great Gallery can be interpreted in a purely utilitarian way, as an amazing oblique lift, allowing to haul up the 52 monoliths made of granite of the King's room, up to a height of 65 meters.

There are already several pieces of evidence showing the veracity of the hypothesis. But one should check for a series of conclusive proofs which are to be found in situ: on the plateau (analysis of the stones of the bed's natural fracture), on the pyramid (observation of the top and the disposition of the edges), and inside the pyramid (examination of the inside device). From a historical point of view, one finds, surprisingly, that the description provided by Herodotus<sup>2</sup>, generally ruled out nowadays because of its complexity, turns out to be technical, precise and accurate. It is corroborated by modeling, experimentation and observation, highlighting the observations of R. Lepsius and the intuitions of A. Choisy. Furthermore, this way of reasoning allows to situate the Great smooth Pyramids inside a "technical continuum", since the first agricultural removing of stones of the Neolithic period, which is based on an universal method of construction known as "accretion-raising" to actual constructions still practiced nowadays in some rural environment (shepherd's shelter, field

stoning etc) . This method generates, puts in order and formalizes the whole array of tumulus-shaped edifices, including pyramids with degrees, within space and time.

This approach is innovative and predicative, consisting essentially of practical questions and answers brought up by the different scientific, technical and operative disciplines contributing to the "Art of building". It proposed paths of investigations which demand to be completed and checked by the international community. This work is also a rational contribution to the History of Techniques, to Egyptology and to Culture in general. It might revive the debate, or even close it, about the building method of Pyramids. It allows a totally new approach to the first chapters of the history of the Art of building.

### PRELIMINARY STUDIES - EPF-L (Switzerland) (1994-1997)

For the past 5000 years, the system that was used to erect the great Egyptian Pyramids has remained a mystery. None of the various theories put forward until this day are fully satisfying from a builder's point of view. And modern technology and technique are about as ineffective.

From Antiquity on, two interpretative models are in opposition: "mechanical" theories<sup>3</sup>, starting with Herodotus, against "ramp"<sup>4</sup> theories following Diodore of Sicily<sup>5</sup>. "Mechanical" theories have been limited to the research of the mechanical device which would allow the lifting of a block the height of one stratum, without considering the "building system" as a whole, they are inapplicable when considering the placing of the monoliths of granite which top Cheops' room located at 45 to 65 meter high above the ground inside the pyramid.

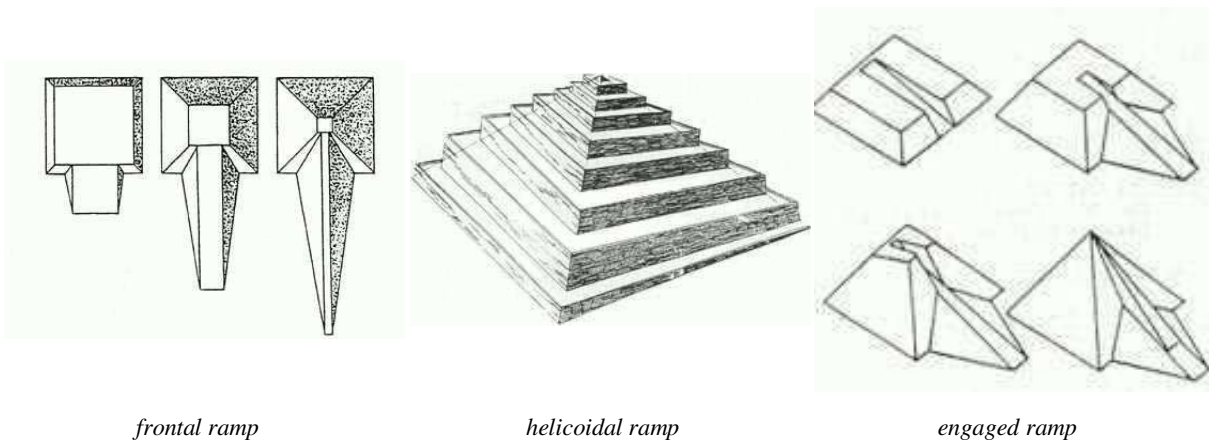


Figure 1: Ramps suggested in "ramp" theories.

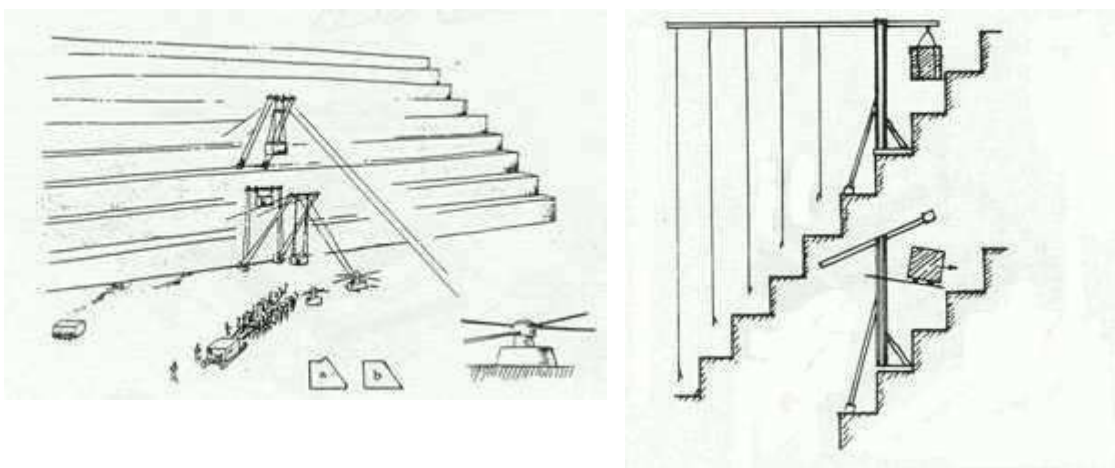




Figure 2 : Possibles machines proposées dans les théories machinistes

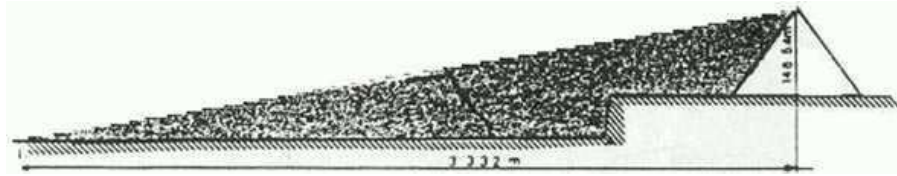


Figure 3: frontal ramp simulation in situ

None of those theories offers satisfying evidence to the architect/engineer/practitioner because, before being an archeological and egyptological object, pyramids are, essentially, a built edifice, a civil and architectural piece of engineering. The logic has remained the same over the millenia: economy of effort and means, technological development and structuring of tasks.

- On one hand, the architect/engineer/practitioner cannot admit the "ramp" or "mixed"<sup>6</sup> solutions, because they are too radically opposed to the Art of building. He will refuse the remote origin of materials, the principle of any massive subsidiary work and the gigantic spread of tasks that these theories suppose; moreover, all these "rampist" theories, whatever they may be, from the most simplistic ("frontal" ramp of J-PH Lauer) to the most sophisticated ("helical internal" ramp of J-P Houdin) require the prior creation of a horizontal platform on a site with a slope of 10%. What to do with these excavation materials?
- On the other hand, if the use of a lever is generally admitted, the "mechanical" theories remain at an embryonic level.

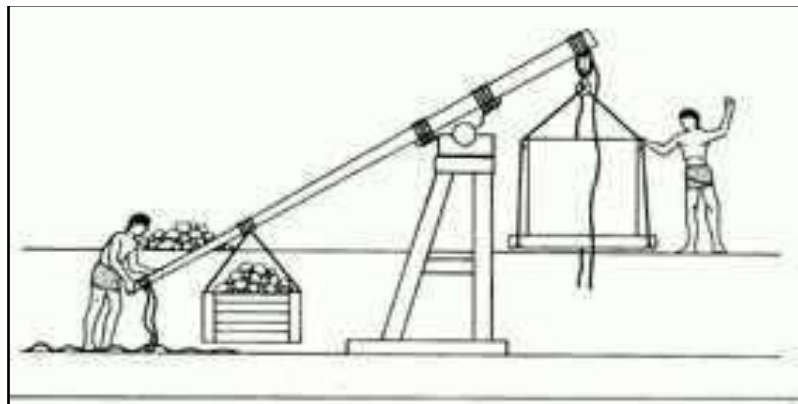


Figure 4: lever arm on tripod suggested by J.P. Adam, if the principle and the scale seem accurate, the counter-weight could be "living" workers used as dead weight!

- "ramp" theories suggest the lifting up, by sliding on a ramp or "levee" of the monoliths and the rest of the necessary materials. This subsidiary construction work, which will need to be destroyed afterward, will require more effort than the erection of the pyramid itself.
- a third group called "mixed" theories suggest the building of a ramp going up to the King's room then the use of a lever.

## A SCIENTIFIC, TECHNICAL and OPERATIVE RESEARCH

This article is the result of lengthy scientific research. It is technical in its application and operative in the determination of the Know-how, the tools and their usage. It follows up on the mechanical theories and it is devoted to describing a constructive system as a whole - which is innovative among the archaeological researches in situ.

The research is based on taught knowledge and practical skills in reference to the original, interactive and predicative model and, on the verification, through archaeological observations, of the construction work and its surroundings, in situ.

The research rests on three fundamental postulates:

- the materials constituting the body of the pyramids are taken on the spot, on the plateau of Giza according to the principle of "exploiting all around to abound in the centre»; by contrast, the granite monoliths come from Aswan, 850 km away in the Nile valley.
- the building principle is necessarily simple, efficient, repetitive and effort saving. It is based on the principle of "always erect on what has just been erected."
- the set of tools must be of a simple usage and easy to make, according to the technological context of the era<sup>7</sup>.



*Figure 5: The three great smooth pyramids of the Giza plateau are located at the centre of the quarries where the material of the pyramids comes from*

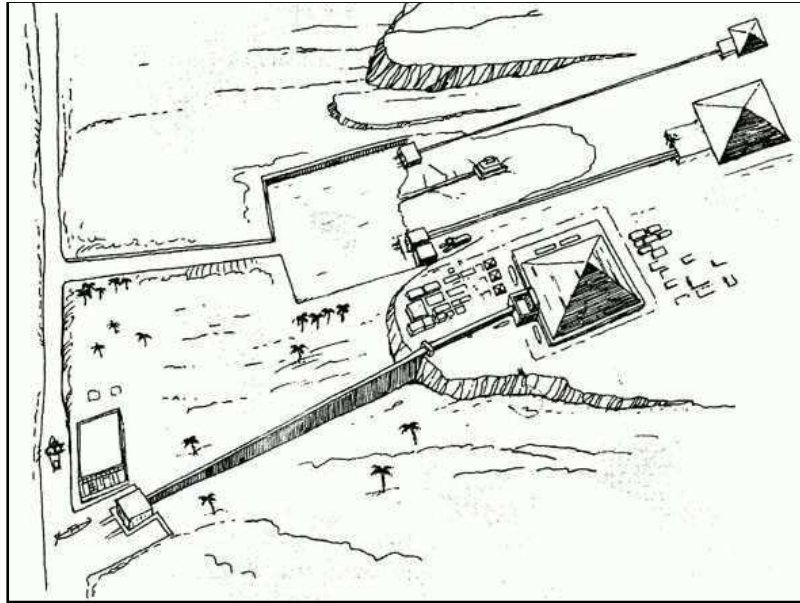


Figure 6: Reconstruction of the Giza area, suggested by G. Goyon

### THE PROCESS OF “PYRAMIDAL GROWTH”

To begin, the distinction between the blocks made of limestone (2.5 tones average) which constitute the body of the pyramid, and the 52 monoliths made of granite (30 tones average) which cover the King's room must be stressed. Logically enough, these two types of blocks cannot be brought into play according to the same lifting and transportation technique:

- the first ones are hauled up from one foundation to the next with the help of a simple “*machine made of short pieces of wood*” (dixit Herodotus): a lever on a tripod, generating a “stairs” system,
- the second ones must be hauled up by sliding on slopes that will be built at the right time by anticipation of the construction of the North face, following the same (“stairs”) system,
- at last, a third kind of stone - limestone or granite - forming the last layer, will be laid according to the same above system and then cleaned: “*So we finished the pyramid beginning with the top and bottom floors to the base of the building*” (dixit Herodotus).

The method of construction is a true constructive system known as the process of pyramidal growth which is based on:

- the basic displacement of a 2.5 t limestone block, elevated at he height of one layer (.7m), with the help of a wooden tripod
- this block is then laid on two other blocks
- with an overhang on the inner side, corresponding to an entablature on the exterior side of the edifice. This layout is typical of the intersecting joints equipment (in both axis) that secures the optimal coherence of the edifice. It however necessitates an adjustment of the foundation of each block that, as we will see later, are not regular.
- the repetition of this recurring movement, block after block, like stairs, side by side
- generating successive layers which fit into each other, starting from a little pyramid in the centre of the basis and allowing its increase through simple homothetic transformation, through simple additional repetition.





Figure 7: To lift and to lay a block onto two other blocks makes up an algorithm

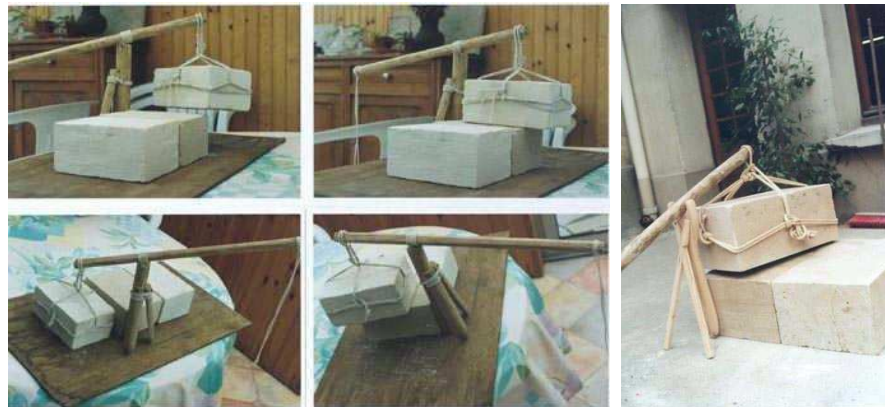
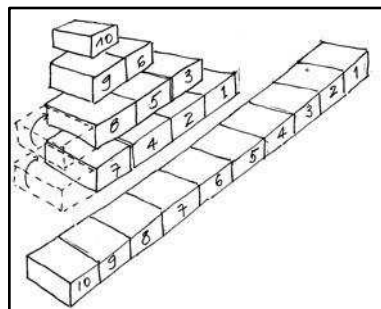


Figure 8: modeling at scale 1/10 and at scale 1/3

This process is easy to model, in the old days just as nowadays, with more or less standardized elements: bricks, pieces of sugar, stones. The process can be modeled with an algorithm. It can only generate pyramids and is therefore interactive and predicative<sup>8</sup>.



Schematic diagram of stacking

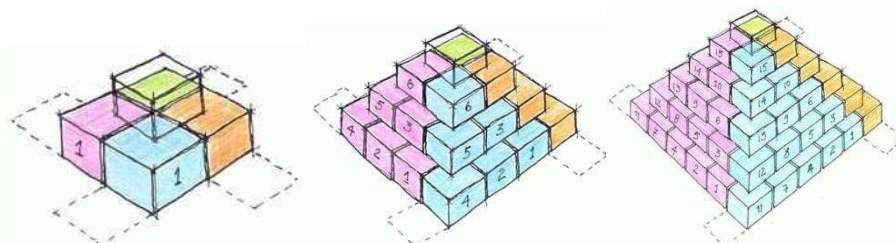
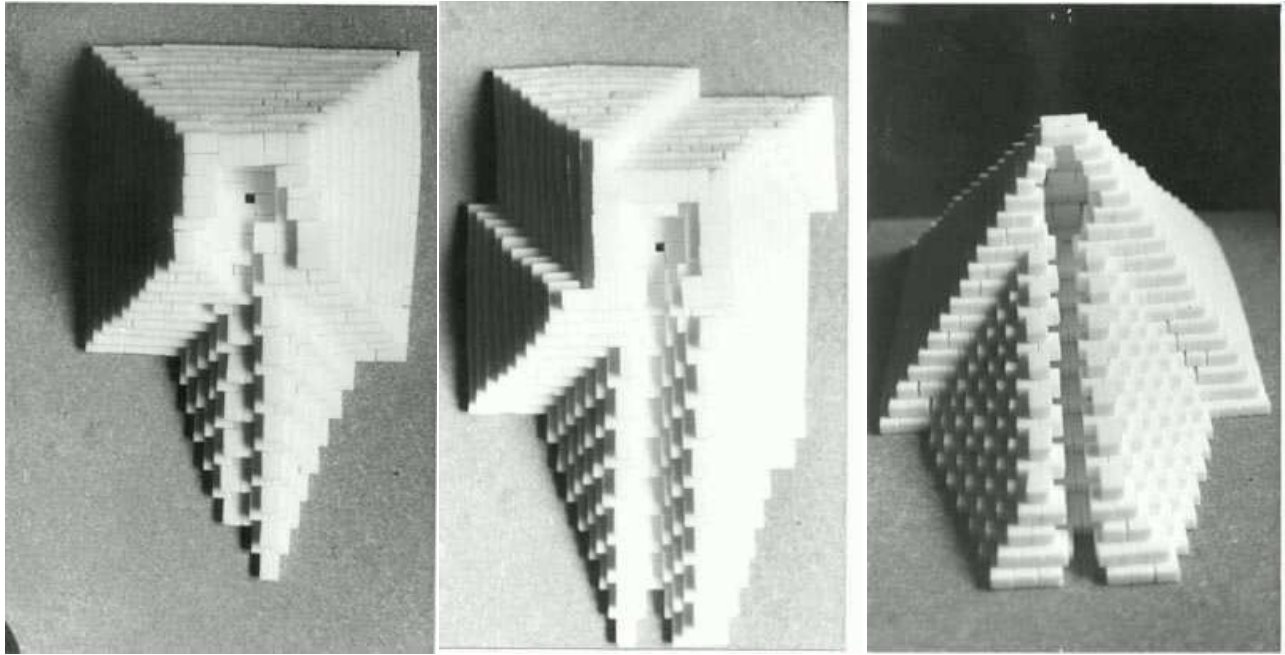


Figure 9: modeling of the "pyramidal growth" process, by successive envelopes, from an elementary [4+1] little pyramid at the centre of the base, side by side, block by block according to the algorithm

The model is interactive:

- the process allows to build, at the time of the erection of the body of the pyramid, the entire interior devices of Cheops' pyramid: rooms, corridors (horizontal, ascending and descending), Great Gallery and ventilation shafts, the shapes and locations of which are corollary to the system
- by anticipation of the construction of the North face, an inclined plane is built, along with a number of other parallel and superposed inclined planes, where, at the right time, a corridor and/or Gallery can be installed
- the granite and limestone monoliths of the King's chamber, will then be slid up, in the open, by way of those inclined planes. The ascending corridor and the Great Gallery are the archaeological proof of the existence of these inclined ramps.



*Figure 10: by anticipation of the construction on one side, inclined plans can be built and a corridor, a room that will end up inside the pyramid, after the building of the four sides is complete*

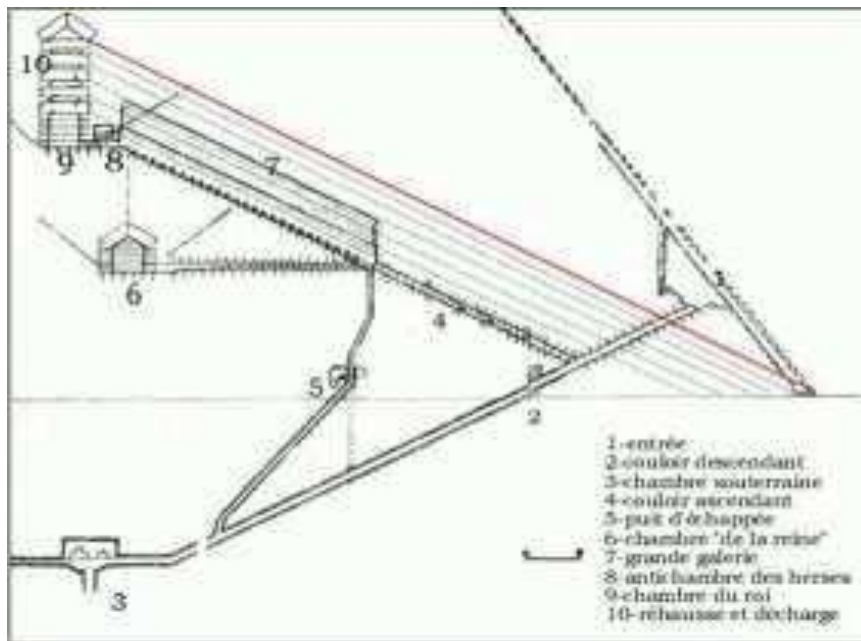


Figure 11: the inclined plans allow the positioning, through sliding, of the monoliths

(average of 30 tones each) constituting the King's chamber, the lifting devices and the relieving arch which corresponds to the last possible inclined plan from the foot of the pyramid:

(1- entrance; 2- descending corridor; 3- underground room; 4- ascending corridor; 5- shaft view; 6- Queen's chamber; 7- Great Gallery; 8- portcullis anteroom; 9- King's chamber; 10- raising and discharge.)

- the Great Gallery in profile : central slide and lateral benches/mortises regularly placed all along as a "trammel", and the 5 or 6 future pad-blocks<sup>9</sup> made of granite which, put together (5 of 6 tons each), will serve as counterweight. The Great Gallery must be understood as an "extraordinary oblique lift", allowing hauling up - by the balance of forces - all the monoliths of the King's chamber and the relieving arches.

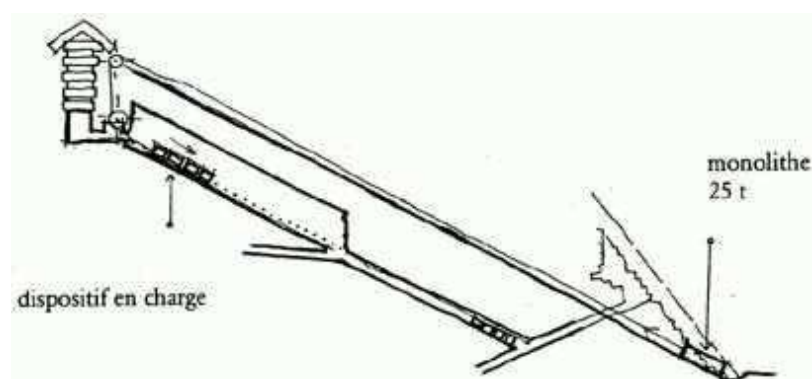


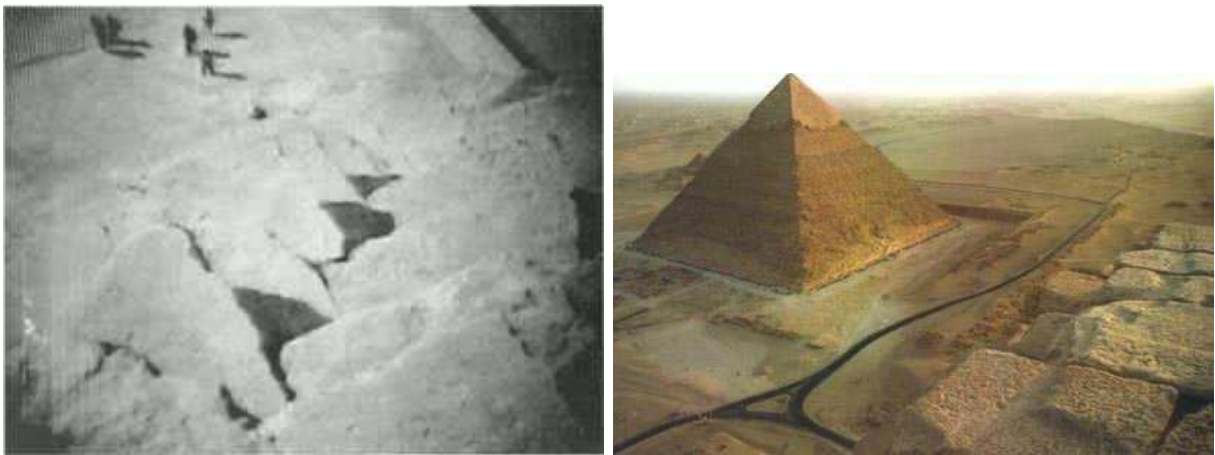
Figure 12: an "extraordinary oblique lift", with rack, counter-weight (pad-blocks)

- these granite monoliths are used to support and raise the relieving arch<sup>10</sup> made of limestone (sensitive to compression ) to the correct height to prevent the descending charge from pushing the ensemble into the void of the Great Gallery. Indeed, this would put<sup>11</sup> at risk the balance and the solidity of the construction.

- all these devices will then be contained inside the pyramid by the continuation of the building on the four faces.

The model is predicative and can be tested. It requires that:

- the monoliths of this relieving arch must be placed last, via the set of slopes and the elevator. They actually correspond to the last possible inclined plane to be included inside the pyramid. The line, parallel to the ascending corridor, drawn from the bottom of the pyramid verifies it.
- the angle of the pyramid being given, the angle of the ascending corridor is its corollary, imposed by the covering (1/3 and 2/3) of the blocks. For an angle of  $\text{tg } \alpha = 1.25$ , which is the case for Cheops<sup>12</sup>, the angle  $\beta$  of the ascending corridor is then such as  $\text{tg } \beta = 1/2$ , which already seems to be verified.
- the blocks of the stratum (of an average proportion of two cubits by three) must be laid perpendicular to the side of the pyramid on each side. The fact that each edge belongs to one of the sides and that the angle blocks cannot be crossed comes as a result. These blocks are then easy to remove by pushing them to fall down. This organization has been verified.



*Figure 13: layout of the blocks on the S.W. edge and on the top (notice the notches)*

- the juxtaposition and the superposition of blocks of different heights impose, for each block placed for good - when its name changes - a notching of the inferior block, to obtain a flat and horizontal foundation, in order to achieve the right sequencing and the right distribution of the charge and, ultimately, the solidity of the edifice. These notches are visible on the stratum of the pyramid, and are particularly easy to locate on the edges and the top of the pyramid. They even constitute a well known system of quarry stone wall named "horizontal recess device" by A.Choisy<sup>13</sup> that he qualified as "the most sparing device".
- the perpendicular layout of the blocks on each side of the pyramid and the recovery of the blocks on the leveled top of the Pyramid of Cheops seem to also be verified by the optical restitution in "camera lucida" provided by E.W. Lane in 1827. It becomes then possible to know exactly to which side and which layer each block of the top belongs.



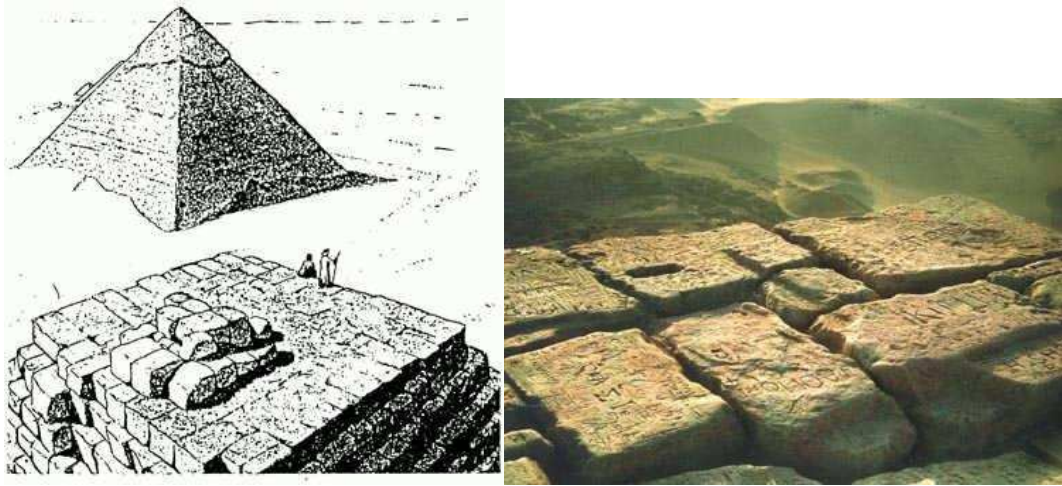


Figure 14: optical restitution of the leveled top of Cheops and interpretation: a color for each side by the author

Finally the pyramid will be covered by a last coat brought into play in the same way -made of fine limestone, of granite, or of stone coming from the same origin- that will be then cleaned by knocking down the nosing of the stratums, "the pyramid will be completed starting from the top" - dixit Herodotus - because this cleaning executed backwards, from top to bottom, eliminated all the entablatures on which to rest the tripod. It is then impossible to add any other block to the edifice.



Figure 15: Mykerinos, last granite "cleaned" envelope

### Herodotus was right

As a matter of fact, Herodotus' description of the building method of Cheops' pyramid as a whole - the Investigation - Book II- Articles 124 and 125 - that has remained impenetrable until now, is elucidated and corroborated by this scientific, technical and operative research. The Greek technical terms such as "bomides"<sup>14</sup> and "crossai"<sup>15</sup> become respectively explicit as "block used as base - entablature" and "block going up the stairs - laid in an overhang way," each block being called "crossai" when it climbs the stairs and "bomides" once laid in its place, and then serving as the base for the next "crossai".

Pharaoh Cheops was in his sarcophagus, still in position in the King's Chamber where Caliph Al Ma'moun found him in 827, after discovering the start of the ascending corridor, hidden by a dressing block (before it fell), provided for this purpose and included in the covering of the descending corridor.

According to the legend twice repeated by Herodotus, Cheops should have been buried under his pyramid (and not inside his pyramid) "on an island surrounded by water." The only purpose of this legend was to deceive the graves' plunderers, and it obviously worked for 35 centuries! Herodotus was nevertheless careful enough to mention it as hearsay.



Actually, Herodotus' explanation has been offering the solution that Egyptologists- archaeologists were expecting to find in a hieroglyphic text or through a fortuitous discovery, for 25 centuries. The translation we are proposing needs however to be verified.

### Origin of materials/

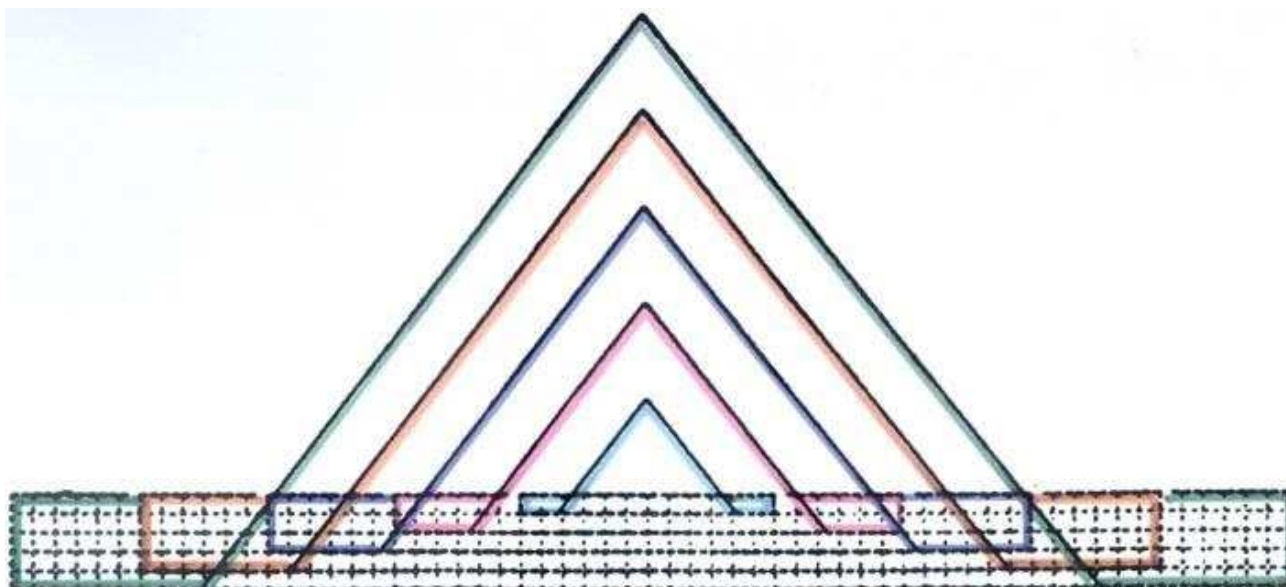


Figure 16: Diagram of the relationship between the successive quarries and the successive envelopes built on the basis of a double surface quarry of that of the pyramid, in section (hypothesis stated since 1997).

### DOCTORAL THESIS - INPL / ENSMN / Laego / Civil Engineering - 1999-2002

The blocks of limestone constituting the body of the pyramid, according to our postulate, are taken from the plateau of Giza, at the closest, by directly exploiting the horizontal stratum of the plateau,

- The verification of the conformability of the stone from the plateau of Giza (Lutetian, Medium-Eocene, Nummulitic limestone) with the three Great Pyramids, and the spotting by aerial views of the exploited areas can easily be performed

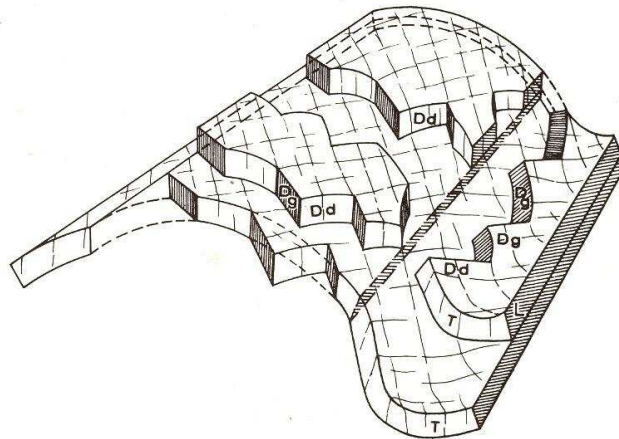


Figure 17: remains of the quarries at the foot of Chephren, and at the N.W. corner of Mykerinos (covered in sand)

- the remains of the quarries are visible at the foot of Chephren and Mykerinos<sup>16</sup> (covered in sand). From a geological standpoint, the plateau of Giza is made of specific limestone - Middle-Eocene, Nummulitic

- and is, by tectonic deformation, a slight anticlinal fold that has obviously caused an easily analyzable (double) system of fracturing of the natural rock<sup>17</sup>:

- a first system of large fractures (open diaclasses and faults, very easy to find) that are parallel and perpendicular to the axis of the tectonic fold and caused by the compression,
- a second system of sub-orthogonal, tight fractures (closed diaclasses, denser and thinner, less visible) that are diagonal, on the left and on the right, to the axis of the fold and are also caused by compression.
- according to the theory developed by Prof. M. RUHLAND<sup>18</sup> concerning the distribution of the natural fracturing networks of the rocks (stratified sedimentary rocks) that can be summarized in the diagram which he proposes, hereafter:.



Organisation des fractures dans les plis  
 a) système de diaclasses parallèle-orthogonal à l'axe du pli. Diaclases longitudinales (DL) parallèle à l'axe du pli, diaclasses transversales (DT) perpendiculaire à l'axe  
 b) système de diaclasses diagonales. Diaclases diagonales droite (DDd), diaclasses diagonales gauches (DDg) par rapport à l'orientation axiale du pli.

Figure 18: Theoretical scheme of distribution of natural fracturing networks of rocks.

- the geologic map of Cairo and the area around Cairo shows the NE-SW orientation of the tectonic folding and of the faults at the edge of the plateau of Giza.
- by comparing this theoretical scheme with the Plateau, it is then possible to state a new hypothesis called "geological": that is to say that the three pyramids of Giza are therefore arranged and oriented according to the geology and natural fracturing rocks (engineering geology)
  - a) they are lined up along the top of the fold, parallel to the axis, where the stratum are quasi-horizontal, and therefore much easier to exploit,
  - b) they are orientated N-E and E-W according to the fracturing - the thinnest - the metrical diaclasses, themselves diagonal to the fold axis.

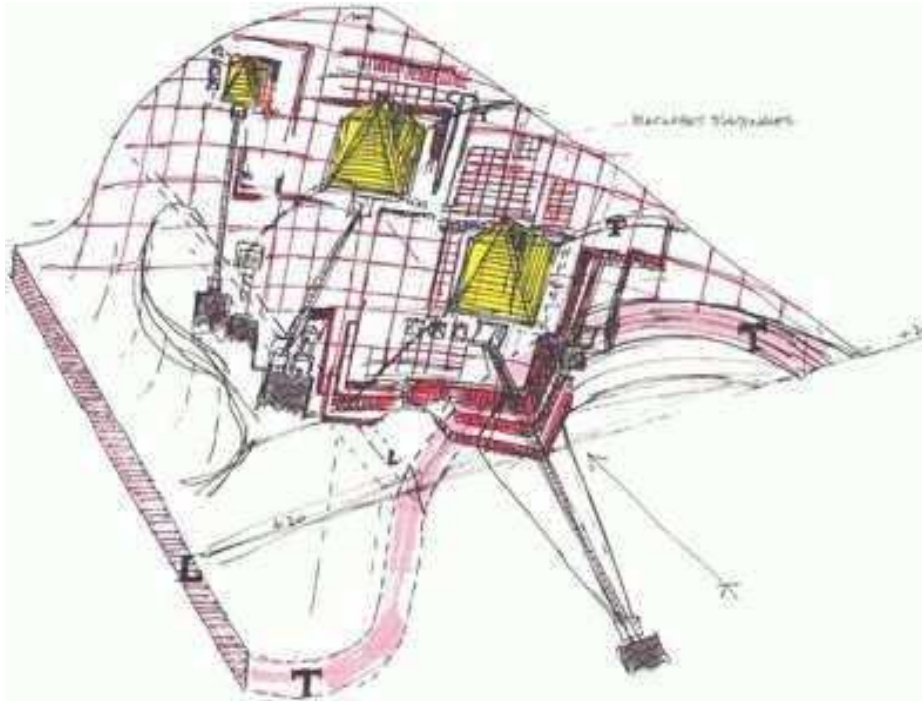


Figure 19: *schema of the system of the natural double fracturing of the rock on the Giza plateau (hypothesis to develop and verify in situ).*

Nowadays like in the old days, no one can ignore the orientation, the geometry, and the frequency of this fracturing system at the risk of only extracting chipped, deformed or cracked blocks from the quarry, that would be difficult, if not to say impossible, to use

- The extraction of the blocks, in a horizontal open-cast quarry, will be accomplished gradually depending on the needs, from the nearest and the most accessible places. Stratum are then cut up following a grid of trenches (of a man's width and orientated according to the thinner, diagonal fracturing system) that dictate large blocks to be lifted off: the "démisage". The notches made in order to lift off the larger blocks are still visible on the ground of the quarries around the pyramids, on the remaining strata and on some of the used blocks.

This extracted large blocks will have to be cut once again (according to the fracturing system) in order to be moved and used, the blocks being so to speak "pre-cut" in the quarries, they won't therefore require much trimming work afterward.

### **"GEOLOGICAL HYPOTHESIS"Development:**

It is based on the work of various geologists whose respective contributions must be mentioned here; their conclusions will be complemented and verified in my postdoctoral studies:

- 1) DJ. AÏSSAOUI, initiated me to the recognition of the different conjugated networks of natural fracturing of the rocks of a simple anticlinal fold with small curvature (of the same structural model as the plateau of Giza) in an abandoned career in DOLE of Jura (career SOLVAY of "la Combe Truchêne"). He kindly offered me his personal copy of the edition of "researches on the natural fracturing of rocks (1969 -1972) as well as the DUNOD Dictionary of geology (5th edition) that I used a lot.

He accompanied me to the Société Française de Géologie SFG to buy the "Geological Map of Cairo and Surroundings" to determine on the map the orientation of the axis of the anticline fold of the Plateau Giza NE / SO in N 45 and he came to check on it, in situ, in 2003).

- 2) The contributions of Prof. A. YEHIA, Egyptian Geologist (1985):  
The thesis of this Egyptian geologist dates from 1985 can be summed up in:
  - the study of the structural and morphological evolution of the folding of which the Plateau of Giza constitutes only the western part, the eastern part is under the Old City of Cairo, the center is a subsidence "graben" by which the Nile could pass and deposit its alluvium.
  - the characterization and schematization of the anticline folding (comparable to a simple fold of small curvature) that constitutes the Plateau of Giza :
    - orientation of the axis of the anticlinal fold in North 45°
    - orientation of the main open joints:  $\Delta$  Longitudinal in North 45° and  $\Delta$  Transverse N 135°.
- 3) The contributions of J. CUVILLIER, French geologist (1930):
  - Orientation of the NE / SO fold axis (without further details)
  - Slanting of the east of 6 ° (10%), less southerly
  - Detailed stratigraphy of the different geological layers.
- 4) The contributions of Prof. A. STROUGO, Egyptian geologist, at the Faculty of Geology of Ain Shams University / Abassya / Cairo: (Ppt illustration),
  - Nomenclature (according to R. SAÏD) on the Mokattam Training Courses (English)
    - Lower (folding): 1st cuesta
    - Middle Eocene filed ON LAP): 2nd cuesta
    - Superior Eocene (deposited around anticlinal duplicates without covering it completely)
    - Synthesis of the stratigraphy of the Plateau (Illustration Ppt)
- 5) The contributions of Prof. OMARA, Egyptian geologist (1952): consists of the establishment of fracturing diagrams on the Giza Plateau that will allow to verify the orientations and the axis of the fold and the main (open) joints - which hardly varies from one to the other of the pyramids and seem particularly precise on the 4 cardinal points, for Cheops.

However, the Cheops pyramid being the first of Giza's 3, it seems illogical that the following 2 have "lost the North"; in fact, the orientation of these pyramids is not voluntary but the consequence of the tectonics that has deformed the Plateau:

- The fold axis is oriented NE / SO in North 45 °, as well as Longitudinal faults and declases ( $\Delta$ L) parallel to the axis, thus diagonal with respect to the geographic North,
  - Transversal faults and main joints ( $\Delta$ T) are oriented NQ / SE in N 135 ° according to the theoretical model,
  - The network of "diagonal" joints (with respect to the axis) which precuts each stratum according to a "canvas" determining "unit blocks" that is to say whole-not cracked according to their respective regimes, is thus found - by a simple set of circumstances - oriented NS / EO.
- 6) MY OWN "in situ" OBSERVATIONS  
These observations are of several kinds:
    - borrowing areas, traces of extraction, traces of detachment of blocks called "dismantling", boxes of demisage on the ground, on the rock in place (base of Chephren, west face),
    - stratification of different layers and identification of fossils-markerstypes of Nummulites (small and large), rare or extremely abundant, lying or standing, seaweed, sea urchins, etc.
    - traces of tools (woodpecker, chaouta, gouge, on the base of rock-mother in place of Chephren and on the face of size of the plateau behind Chephren,
    - especially upstream of the Khent-Khawès pyramid, where one can observe the beds of the Auversian layer (a) and the vertical "diagonal" fractures, more or less dense depending on the thickness of the strata. One can follow the Auversien bed to the SE foot of the pyramid of Chephren (Ppt illustrations)
    - one might hypothesize that the Upper Temple of Chephren could be partly composed of Auversien in its highest part.
  - 7) Table of the Geological Synthesis: structural and stratigraphic and in situ observations

Plateau de Guizh, synthèse stratigraphique										
MOKATTAM	Lutétien supérieur	OBSERVATORY FORMATION	Partie supérieure non affleurante	AUVERSIEN	(b) Calcaire blanc à bryzoaire	4 m	dissimulé dans le wadi			
					(a) Calcaire dur à petites Nummulites et Gastéropodes	6 m		7'	7	Tête du Sphinx Khent Kawès cuesta supérieure
	Lutétien inférieur et moyen	MOKATTAM FORMATION	SUPÉRIEUR	LUTÉTIEN	(g) Calcaire blanc exploité "pierre à bâtir" à nummulites <i>Curvispira</i> et <i>Loevigatus</i> avec <i>Operculina pyramidum</i> que certains classent en Observatory Formation	10 m		7	6	
					(f) Calcaire à nummulites <i>Gizehensis</i> et <i>Curvispira</i>	4 m		6		sol du Sphinx
					(e) Calcaire extrême abondance de nummulites <i>Gizehensis</i>	5 m		5	5	
					(d) Calcaire pétri de petites nummulites	5 m		4	4	cuesta inférieure
					(c) Calcaire plus blanc	6 m		3	3	
					(b) Calcaire plus tendre (moules, huîtres, petite nummulites)	5 m		2	2	
					(a) Calcaire détritique jaune (pointes d'oursin)	4 m		1		
Rushdí SAID Amin STRUGO		Jean CUVILLIER	Pierre CROZAT	Alice BASTIEN	Repères					

Figure 20: Synthetic table of the structural and stratigraphic geology of the Giza plateau.

- 8) The geological hypothesis was completed by specific geological engineering, from an initial intuition, it has become more structured and detailed, allowing one to understand that the relationship between quarry and construction is dependent on the environment. It now necessitates some complementary studies, verifications and a final demonstration by the recognition of the folding of the Giza Plateau and the 3D computer simulation of paleo-topo- stratigraphy - before and after the construction of the 3 large pyramids - which will have to be compared with the survey of outcrops of the different layers of the plateau to be made, in situ.





*Figure 21: Aerial shot of Cheops' "temenos", showing the quarry exploitation of the blocks according to the secondary fracturing (diagonal to the axis of the fold)*

The rhomboidal shape of the Dashour-South pyramid doesn't come from a concern for making it lighter in order for it not to sink into the plateau; its construction follows the same system of "pyramidal growth" which allows generating this shape. Couldn't the visible depression<sup>19</sup> around the pyramid be the remains of the area of extraction (the quarry) of the same materials it is made of? (This hypothesis needs to be verified.)

### **TECHNICAL CONTINUUM of TUMULAR WORKS**

Some examples are used to date these Tumuli Structures whose constructive mode is the vernacular technique consisting of borrowing around to make it abundant at the center. This requires a lot of manpower.

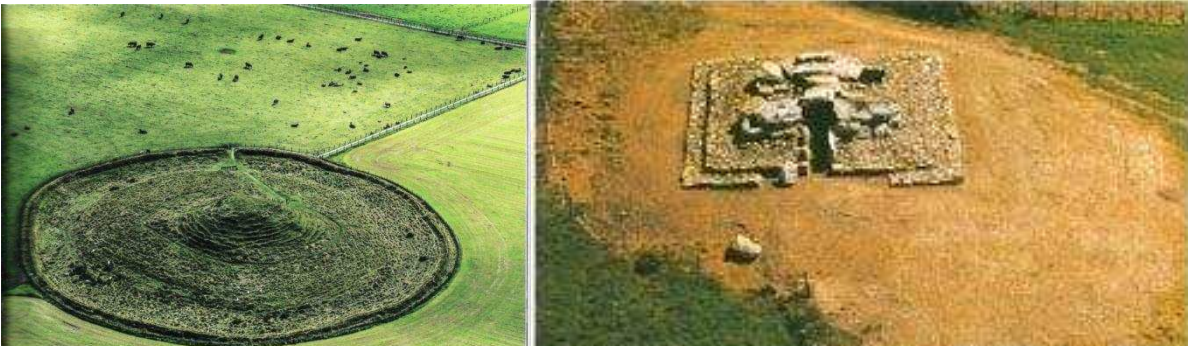


Figure 22 : Tumulus - Tomb Maeshowe (Cyclades) and Dolmen de la Joselière in Pornic (France)

Actually, all the edifices made of earth or stone, since the Neolithic era: cairn, tumulus, dolmen, fortified enclosure, ziggurat<sup>20</sup>, mastaba, step-pyramid and smooth pyramid, tholos, torre, Mycenaean grave, stupa, etc., edifices necessitating important, even enormous, quantities of materials, and achieved with the most rudimentary technical means of extraction and lifting, even without scaffoldings, all pertain to the same method known as "accretion-raising" used when accomplishing the first rural picking of stones out of agricultural exploitations and fields, and maybe coming from this need of "gathering up the heaps" experienced by the first group of farmers-cattle breeders.



Figure 23: Cairn in Barnenez (religious engineering), threshing area in Cipierre (rural engineering)

As a matter of fact, this method is, from the start and by essence, anthropometrical, picking stones out of a pasture or a farming field generates a pile of stones which must be raised by hand, in order to take as little space as possible, the roughest stones are put inside, while the facings are made out of the nicest stones<sup>21</sup>. A man's height is the anthropometrical limit. Then if you want to increase the heap, you have to add a peripheral facing on which to climb in order to continue to raise the edifice until one more man's height is reached, and so on and so forth. This method is called by us "accretion-raising" because only peripheral accretion allows to raise the heap; it explains A.Choisy's schema of construction by degree and imposes the concentric facings and the ascending degrees on these edifices.

This method was applied to the Egyptian step-pyramids<sup>22</sup>, and actually, the first principle «exploit all around and abounds in the centre" and the second one "widening to raise" seems to have an universal value.

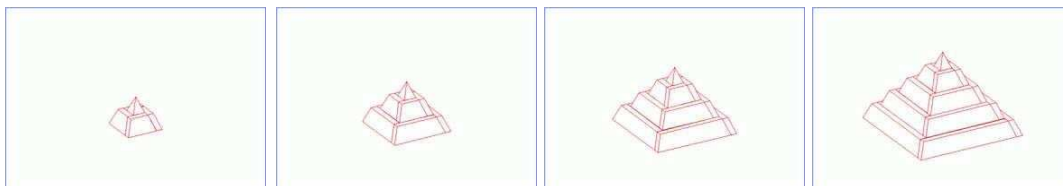


Figure 24: "accretion-raising" system applied to any step-pyramid (like Saqqara) (by P.Crozat and G. Agonsè)

A computer simulation of this method was done and can be applied to every step- pyramids. It allows surmising that, whether they are small or large, solar temple or pyramid, they represent more or less advanced stages of a similar project. On the contrary, the Pyramid of Houni-Snefrou in Meidum and the Sekhem-khet both qualified as "unachieved" are nothing but two more or less advanced stages of destruction. (schema).

And even the way of thinking, the cosmogonic, theogonic and anthropogonic perception and representation of the world, as also the numerical notation of the growing arithmetic according to G.Ifrah<sup>23</sup>, pertain to the same generic concept of increment through successive layers fitting into each, used in the building of the pyramids, to such an extent that it is quasi obvious that we face here the only way of thinking, conceiving and representing.

METHODE DE CONSTRUCTION DES PYRAMIDES A DEGRES  
SCHEMAS DE MODELISATION COMPAREES

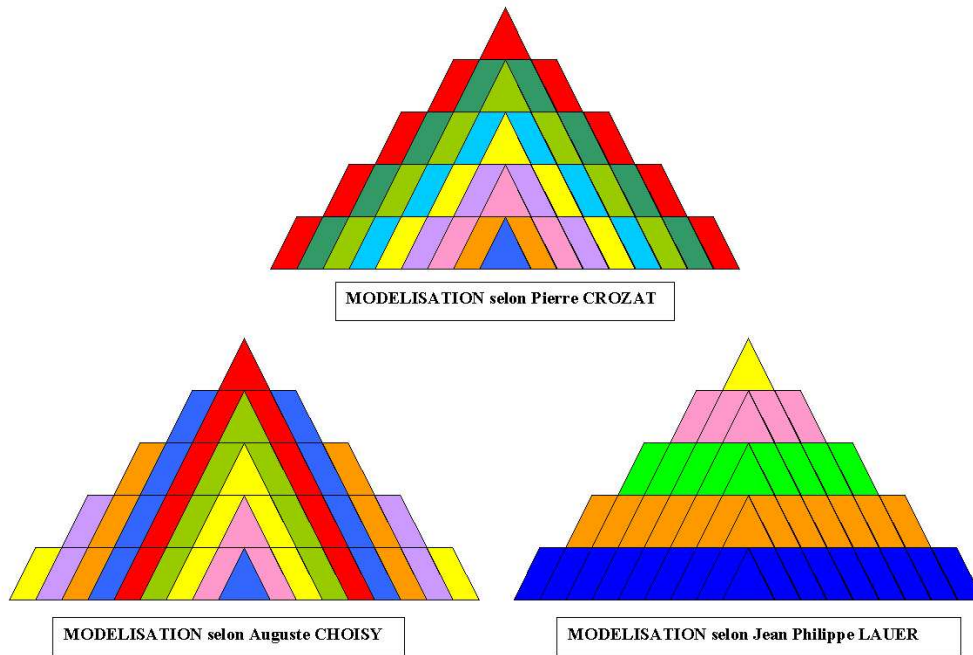


Figure 25: Comparative diagrams of the mode of construction of step pyramids:

- for J-Ph. Lauer: it's a stack of mastabas which requires a ramp to the top
- for A. Choisy: the side walls are made to reinforce the red pyramid (unsuccessful diagram)
- for P. Crozat: the 10 m high wooden scaffolding is based on the built-in degree and is used for the construction of the upper degree (pyramid by degrees = the method adapted to the small module of the material - Eocene Superior - produces the work and generates its form



## POSTDOCTORAL STUDIES (2003-2015)

I proposed different studies that were carried out by other people often more competent in the matter, Prof. Geology, Engineering Geology, students from Ecole des Mines de Nancy, stonecutters, computer specialists and graphic designers, engineers, etc.

2002 -03-04 - Creation of a simulation software for the "relationship: Construction / Career": ENSM Nancy / LAEOGO + ESIAL / Coaching Prof. O. DECK

2002 - Simulation of construction with the "machine" by Fabien PASIELSKY (info graph) p.m.

2003 - Career Experts: Dj. AÏSSAOUI, specialist geologist and J-P. FOUCHER, Stonemason and quarryman:

2004 - A study of DEA Earth Resource Environment on the geology of the Giza Plateau: (conducted by A. BASTIEN, student, supervised by Prof. D. JOUSSELIN at CRPG Nancy)

2004 - Publication of National Geographic Society "EGYPT" between Heaven & Earth ", photographs by M. Bertinetti

2004 - Computer graphics of the successive stages of growth of the Cheops pyramid: (H. ZARZOUR student architect, trainee) 'p.m.)

2004-05 - "Analysis of the mechanical functioning of the Great Gallery of the Cheops pyramid". by S. SENOUCI (supervising O. DECK / ENSMN ° (p.m.)

2006 - World Year of Physics at The Paris Science Area - ESP (M. L

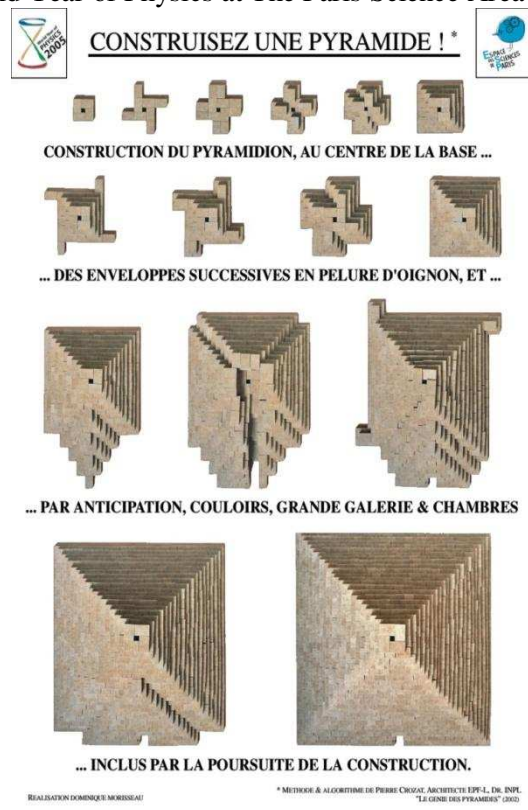


Figure 26: Explanatory panel of the pyramid construction phases (in model)

2005 - Discovery of tectoglyphs by R. PERRIER, French geologist

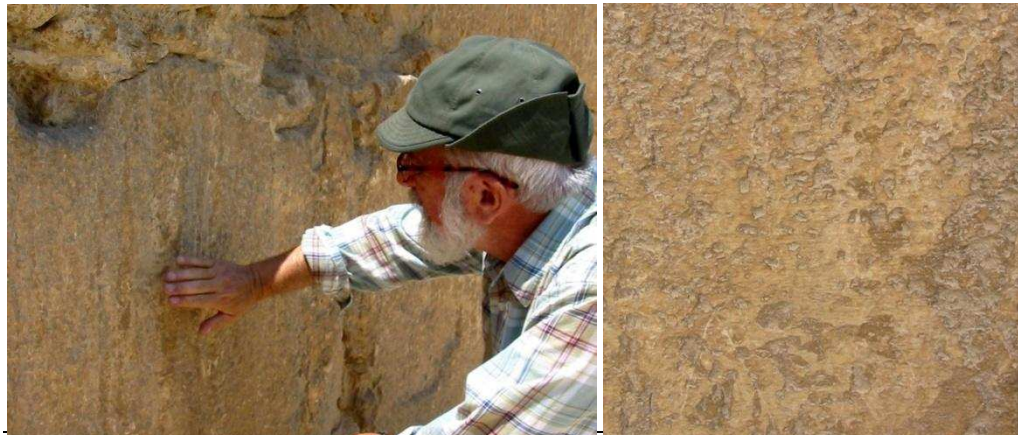


Figure 27: *Discovery of tectoglyphs on the base of Chephren (R. Perrier & P. Crozat - 2005)*

2006 - Visite de carrières d'extraction manuelle (Prof. O. CHERIF)

2006 – EABJM – Ecole internationale en Pédagogie « active » : Programme d'enseignement des sciences au collège

2006-07 – PALAIS de la DECOUVERTE / Paris : Exposition –Atelier – Conférences (P. CROZAT, commissaire).

2007 - Visite et Conférence au NARSS (par TH. VERDEL) et Rencontre du Ministre Hany HELAL (alors Ministre de l'enseignement supérieur et de la recherche et et du Prof. Fathi SALEH : directeur-Fondateur en exercice propose d'accueillir la Table Ronde demandée par J-P. MOHEN (CNRS en Egypte, rapporteur de la thèse).(p.m.)

Attempt to form a multidisciplinary international research, verification and publication team (France / Mines School, Egypt / Ain Chams&Narss Geology School, USA / UC Berkeley, Italy / Florence University): correlation between the evolutions of constructive methods generating the evolution of the forms of the pyramids of Egypt (in stone (aborted attempt because of the political events in Egypt)

2008 - Geology and extraction 2nd career (of the 2 Brothers) (O. CHERIF):

2008 - Making a peak and extracting-dismantling with the Assistant R. MOREL



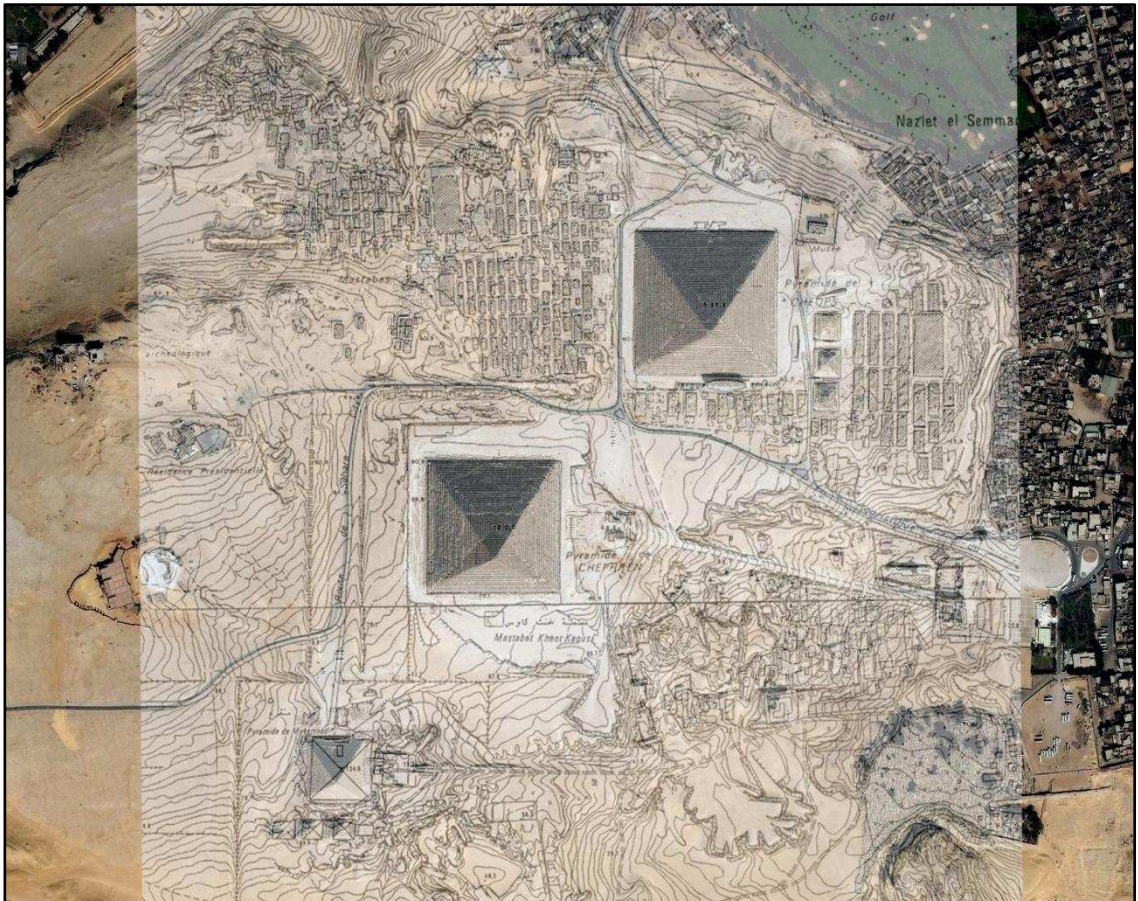
Figure 28: *Peak Manufacturing and Extraction Surgical Trials – Dismantling.*

2009 - Conference in Ain Shams / A. STROUGO and visit of Saqqara North -Abousir / O. CHERIF

2010 - Work Shop at Planetarium Science Center, conference and construction of a pyramid: on the forecourt of the Library of Alexandria.

2011 - Establishment of summary maps of the Giza Plateau





*Figure 29: Superposition of orthophotoplan and satellite photography*

2012-13-14- DOLE du Jura: Realization of cross sections of the Giza Plateau: Topographic (according to orthophotoplan / IGN and Stratigraphic (according to J. CUVILLIER) superimposed: "what nobody had thought to realize"

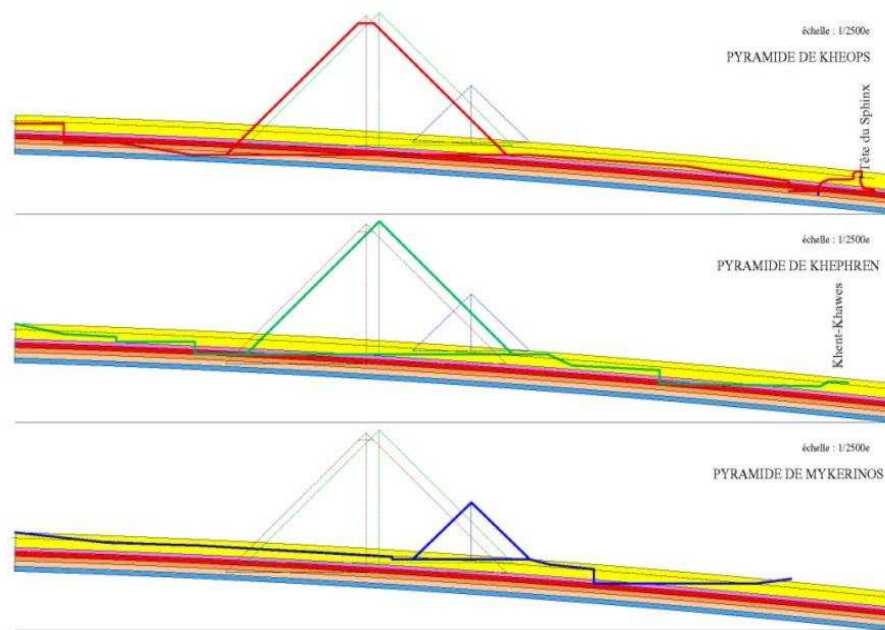


Figure 30: 2D cross sections on the diagonal of the 3 pyramids of Giza.

2014 - 3D simulation of the "paleo-topo-stratigraphy" of the Giza Plateau: First student team (modeler) on GOCAD software (Prof. J. SAUSSE, geo-engineering)

2015 Visit of the Giza Plateau for a final "wedging" of the stratigraphic sections of the Giza Plateau, according to the stratigraphic layer n ° 6 of the stratigraphic synthesis (P. CROZAT and Th. BURLETT, student).

### **3D SIMULATION of the "Paleo-Topo-Stratigraphy" of the GIZA PLATEAU**

On my initiative and at my request with Prof. Th. VERDEL my thesis director:

#### **Establishment of the 3D paleo-topo-stratigraphy of the Giza plateau:**

Establishment of the 3D paleo-topo-stratigraphy of the Giza Plateau, at the Nancy School of Mines (ENSMN) and the Nancy School of Geology (ENSG Nancy) on the Géomodeleur Software GOCAD, Geoengineering Department - GEORESSOURCES Lab . (Prof. J. Sausse and Th. BURLETT, student)

This 3D info graphic simulation makes it possible to visualize and compare - on the constitutive anticline fold of the Giza Plateau (A. Yehia, 1985), the topography taken from the orthophotoplan established by photogrammetry (IGN), the stratigraphy (J. Cuvillier, 1924) thus superposed. - the state of the plateau pre-existing to the construction of the pyramids and the existing state (after construction and today).

## Results:

In a general way this 3D simulation of the paleo-topo-stratigraphy of the Giza Plateau is satisfactory, efficient and sufficiently illustrated (after correction of the limits), the anticlinal fold is well represented and the outcrops are well in their places.

1. It covers the Plateau well enough to answer latent questions:
  - Upper limit of Auversian outcrop–
  - Composition of the High Temple of Chephren (see the Detail Study on the Pyramid of Chephren by P. CROZAT and S. JEANGUILLAUME - 2017)–
  - The Mastaba G 2000 is indeed in the stratigraphy of the Upper Cuesta layer (g) Building stone (thickness 10 m), so it corresponds to a piece of the plateau surrounded by quarry size fronts as leaves in reserve of material ( ?).–
  - What are the constituent layers of each pyramid, how high was the pre-existing Plateau (before the construction) and how much was borrowed "at the perimeter" of each one.–
2. The Sphinx (quarry leftover) indicates the part of the stratigraphy that interests us, namely the "upper cuesta"
3. The Queen's Chamber of the Cheops pyramid is placed on the layer (g) Building Stone, (10 m thick) and maybe slightly recessed 1-2 m in the upper layer (a) Auversian (thickness 6 m) of which "the upper part is non-flush" (according to A. STROUGO).
4. This simulation also makes it possible to clearly show the confusion made by A. BASTIEN between the layers (d) and (b) of the Stratigraphic Synthesis (J. CUVILLIER column), ie an error of 11 m in height; it is necessary to recognize the accuracy of its observation concerning the top of the layer (N ° 6) (f) limestone with Nummulites Gizehensis and Curvispira (J. CUVILLIER) with the NO angle of Chephren (with the dimension 71 m) and with the upper extremity of the legs of the Sphinx, a difference in height of 47 m, corresponding to the dip along this section of the plateau.
5. In partial conclusion, the work of A. BASTIEN, outcrop surveys and establishment (verified) of the lithographic map must be repeated and drawn up contradictorily by experienced geologists.

## Illustrations

This 3D info graphic simulation makes it possible to visualize and compare - on the constitutive anticline fold of the Giza Plateau (A. Yehia, 1985), the topography taken from the orthophotoplan established by photogrammetry (IGN), the stratigraphy (J. Cuvillier, 1924) thus superimposed - the state of the plateau pre-existing to the construction of the pyramids and the existing state (after construction and today), and to highlight, on the one hand, the borrowing pits and on the other hand the rock mass underlying the pyramids, both of which are included in the stratigraphic profile used by the different structures on the Gizeh Plateau site. This evidence shows that these "underlying masses" cannot, under any circumstances, be described as natural hills (dixit S. RAYNAUD<sup>24</sup>, geologist) and the head of the Sphinx an erratic block (or reported) no more than a ruin form relief or eminence (dixit M. LEHNER<sup>25</sup>) any since the Mastaba of Khent-Kawes and the Lower Temple of Chephren that adjoins it are also in the useful stratigraphy of the plateau.



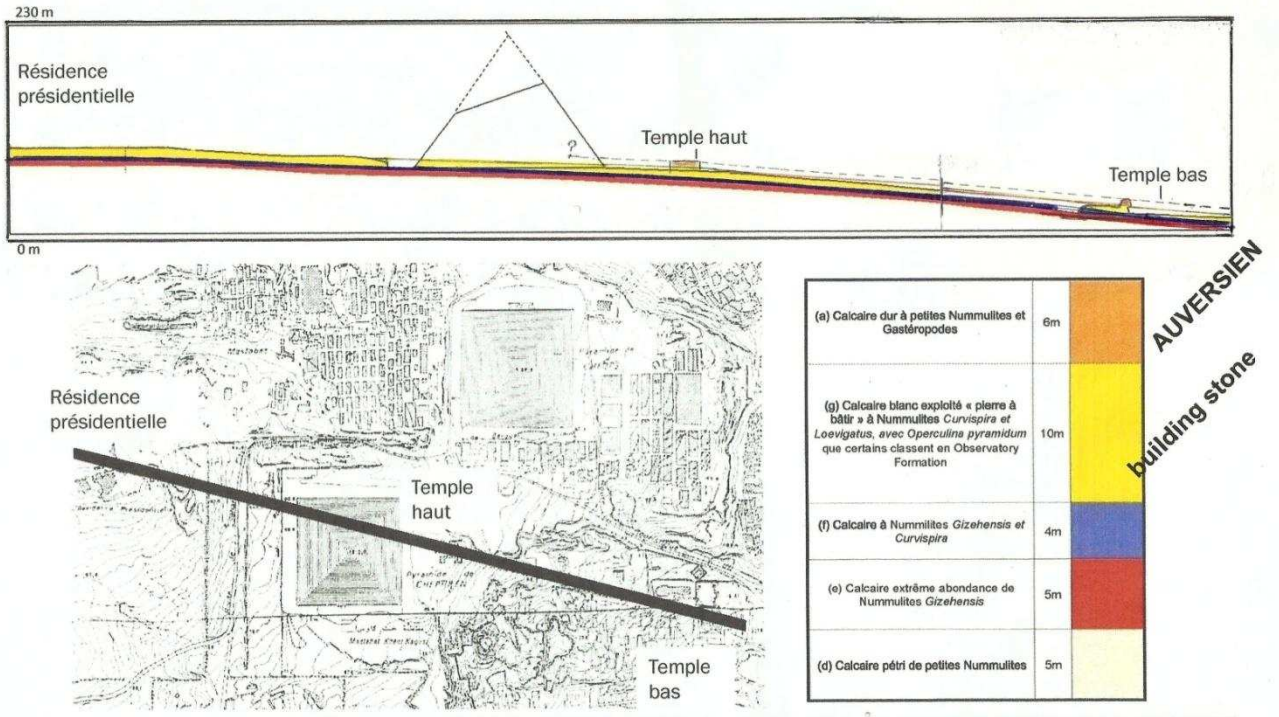


Figure 31: Section on Chephren's Rising Alley showing that the Upper and Lower Temple and the Sphinx's head belong to the Auversian layer (7 ' ) a) hard limestone to small Nummulites & Curvispira

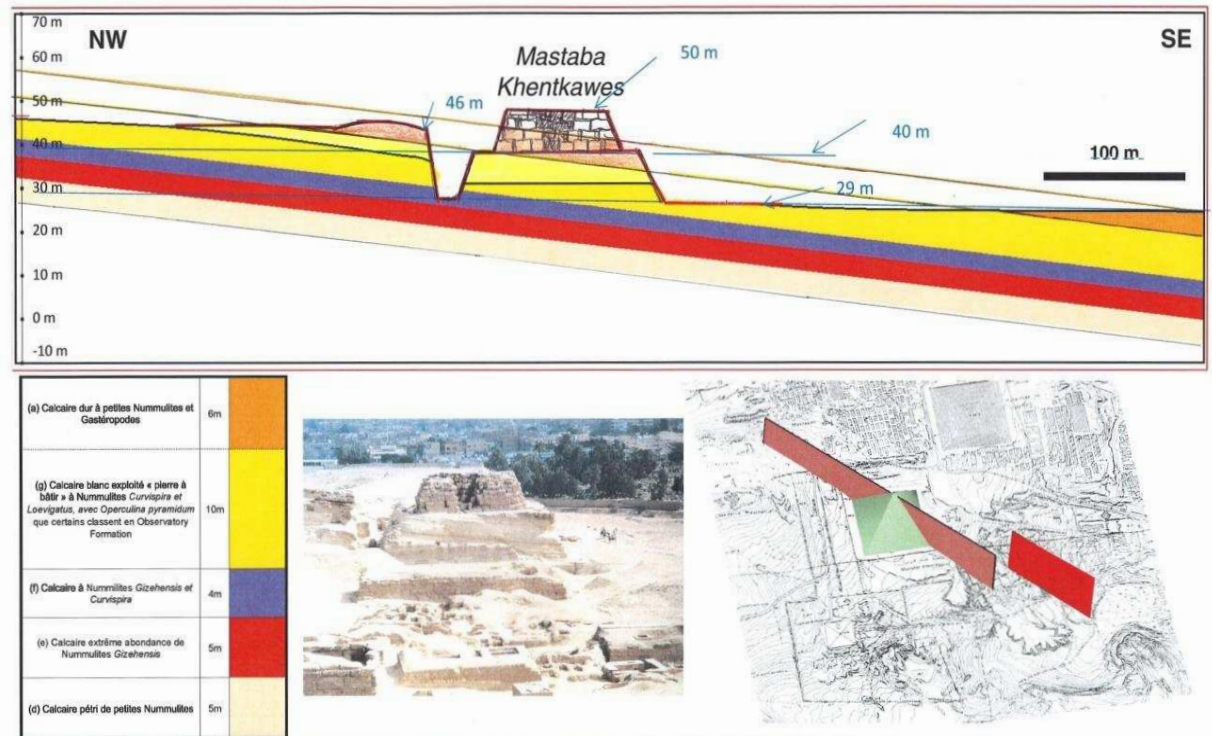


Figure 32 : Coupe sur le Mastaba de Khent-Kawes



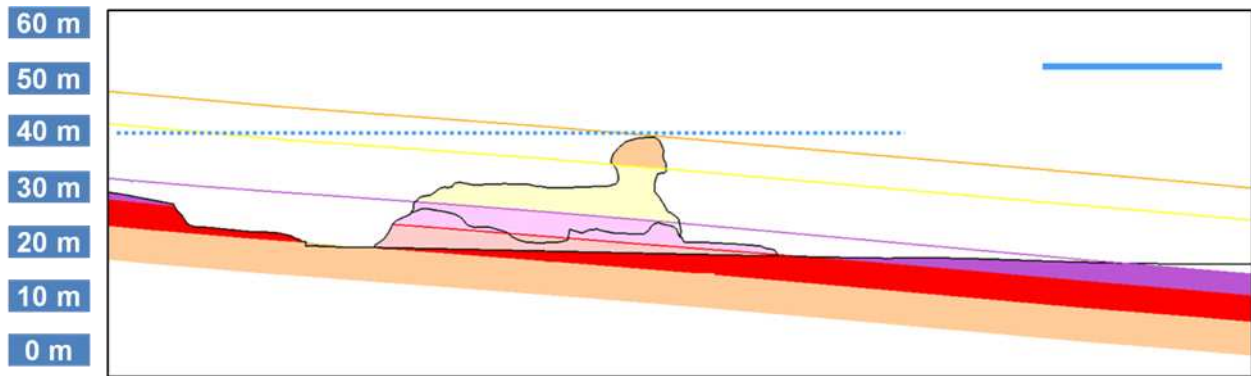


Figure 33: Cup on the Sphinx: his head is Auversien

### Conclusion of the 3D Simulation

In fact, the whole Giza site:

- alignment of the 3 pyramids by their SE angles on the primary network of Longitudinal Diaclases ( $\Delta$ ) parallel to the axis of the anticlinal fold oriented in North 45 °,
- their orientation on the "diagonal" network (with respect to the N 45 ° fold axis, hence N.S.E.O.) of natural fracturing of the rocks, scientifically proven by the Tectoglyphs,
- Extraction zones on the surface, around the pyramids,
- peripheral platforms that are only quarry tiles;
- Mastaba of Khent-Kawes & Mastaba G 2000
- Sphinx who is a quarry leftover
- low and high temples of Chephren

can be explained rationally and logistically only by Structural and Stratigraphic Geology and its extension to the Geology of the Engineer. There is no need, actually, for any other field of knowledge (cognitive, historical, literary, geometric, esoteric or occultist) to be involved.

The mistake made so far is of a cultural nature: on the one hand, the misunderstanding of Herodotus' text because it covers a "technical" notion of the construction outside the field of competence of Egyptology - Archeology and that of translators of ancient Greek (it is precisely the different versions that made me wonder), and on the other hand the "architectural" vision resulting from Greek geometry that will distort the mode of apprehension making it impossible to understand, while the Pyramids and other Tumular Structures must be apprehended in terms of the material to be used, the adapted method of construction and the means and tools available to produce the work and generate its form.

The geological hypothesis is verified by the 3D Simulation of the Paleo-topo-stratigraphy of the Giza Plateau and the solution to the question of the mode of construction of the pyramids of Egypt is not in the domain of Architecture but of Engineering Civil and Engineering Geology.

This "geological" solution is no doubt applicable to all stone pyramids and even to all the tumular works in the world, whether they be made of earth or stone.

**PUBLIC CONFERENCE at the Documentation Center for Cultural and Natural Heritage - CULTNAT at Smart Village, Cairo - Egypt:**

Public lecture given by myself (assisted by Prof. Thierry VERDEL<sup>26</sup>): under the title "Construction of pyramids: the geological hypothesis" at CULTNAT, on 26/09/2017, at the invitation of Prof. Fathi SALEH<sup>27</sup>, (this lecture was filmed)

In front of a "scientific" audience of about one hundred invited people, this conference was about the presentation of my research approach: my thesis "the engineering of the pyramids", my postdoctoral studies and the convincing results of the 3D Simulation of the "paleo-topo-stratigraphy of the Giza Plateau" (GOCAD software) carried out in 2017, in collaboration with Prof. J. SAUSSE, Dep. Geoengineering ENSMN / UMR 7539 Géoresources.

This public conference at CULTNAT authenticates the intellectual property and originality of research, at this date, and provides Egyptology with the incentive for their consideration and recognition.

### **THE SCANPYRAMIDS PROJECT (02/11/2017)**

Initiated in 2015 by the creation of the HIP<sup>28</sup> Institute, the SCANPYRAMIDS Project aims to examine buildings with a non invasive method involving infrared cameras. Thanks to the differences in the temperature of the various dawns, it would be possible to discover cavities, rooms or corridors, inside the monuments. In a second time, another analysis would be carried out thanks to thermal images. Finally, a third method aims to use muons.

The project focuses on the Cheops pyramid and Chephren pyramid in Giza, as well as two other pyramids located in Dahchour. Scientists hope to discover, for example, the true burial chamber of Khufu.

The mission is interdisciplinary, mixing the points of view of artists with those of engineers. The first stage of the work gave rise to an exhibition at the Palais des Beaux Arts in Lille in December 2016.

### **Publication dans la Revue scientifique Nature :**

On November 2nd, 2017, the mission team published an article in the journal Nature which reported the discovery of a new void in the heart of Cheops pyramid. This cavity, called "Scanpyramids Big Void", has a minimum length of 30 meters (the size of an aircraft will say Mr. Tayoubi, Dassault-System).

In view of my own research: thesis, postdoctoral studies, simulation of the "paleo-topo-stratigraphy" of the Giza Plateau, leading to the validation of my "geological hypothesis", made public during my Conference at the CULTNAT of 26/09/2017 (more than a month before the information of the SCANPYRAMIDS Project results), I wrote to four Professors<sup>29</sup> in the field of Engineering, Civil Engineering, Geology and the Cultural and Natural Heritage of Egypt. They all know my research and I addressed OPEN LETTER (dated 13/11 / 2017) to the Scientific Project Manager of Scanpyramids<sup>30</sup>, with the aim to make my work known to the Team and to give my own interpretation of this "discovery" which needs to be verified by other specialists in the field. I also hope obviously, to become part of the team.

My goal in the Scanpyramids Project would be to research and promote the study of the geological environment, the materials, the differences in the density of the stratigraphic layers, the constructive method, the functionality of the interior devices (corridors, Grand Gallery, rooms, antechamber of the King, the 52 stacked granite monoliths), as well as the basic dispositions of statics and materials resistance which are the absolute basis of the construction of those Tumulus Works which are the pyramids of Egypt and of the other tumuli of the world.

According to me, it would be important to curb the discourses on the Secret Chamber of Khufu and its treasures. It is important to maintain credibility and seriousness in Egyptology by reliance on actual facts.

**OPEN LETTER: my interpretation of the possible "great void" in the Cheops pyramid (*facsimile of the original email*)**

OPEN LETTER TO THE SCANPYRAMIDS MISSION  
Addressed to its scientific Director, Professor Hany HELAL,  
following the

Article published in Nature on November 2, 2017,  
« *Discovery of a large void in Khufu's pyramid by the observation of muons* »

A proposal of interpretation, of analysis and of participation in further research by Pierre Crozat<sup>31</sup>, Ph.D.

The SCANPYRAMIDS team recently related in Nature the discovery of a great unknown void inside Khufu's pyramid. Many articles in the international media reported this important finding, and there was an appeal to Egyptologists, archaeologists and other researchers in the domain to interpret this discovery.

In a recent interview given to Science et Avenir (15/01/2016, Aline Kiner), Professor Hany Helal<sup>32</sup> talked about being among the first to recognize the value of engineering studies for archaeology and quotes: "In 2002, a dissertation on a theory<sup>33</sup> of construction of the pyramids was defended at the Ecole des Mines in Nancy". I am the author of this dissertation. Indeed, my advisor was Pr. Thierry Verdel<sup>34</sup> and Pr. Hany Helal was the president of the examining committee.

The area treated in my dissertation, titled "The engineering of the Pyramids" was followed by 15 years of postdoctoral studies and concluded with a 3D simulation of the paleo-topo-stratigraphy of the Giza plateau. It is the result of personal research started in 1990, and is based on scientific, technical and operational approaches:

- scientific: stratigraphic and structural geology, and engineering geology (study of the natural fracture networks of the rocks)
- technical: the art of building and constructive methods, technical continuum of vernacular tumulus type buildings
- operational: know-how of stone building workers (quarry men, stone cutters, assemblers, tools and machines) with the involvement of the Compagnons du Devoir, an age old association of stone builders.

The current state of this research was presented on 26/09/2017 at a conference at the CULTNAT in Cairo, in front of an invited scientific audience. It was followed with an abstract in english on the site academia.edu<sup>35</sup>. The french version can be found on Marc Chartier's french site "Pyramidales"<sup>36</sup>.

Nota: To consult my thesis, see: [thierryverdel.perso.univ-lorraine.fr/recherche/theses/these-crozat.pdf](http://thierryverdel.perso.univ-lorraine.fr/recherche/theses/these-crozat.pdf)

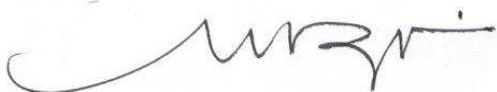
.....

There is for me only one possible and logical interpretation (or even imperative) that would be constructively cautious, namely: "that this empty space could correspond to the realization of a Corridor of discharge arcs in chevron (leaving a triangular void) - probably generous - superimposed on the Great Gallery - according to its slope and sufficiently high placed - which would have the effect of laterally returning the vertical loads of the upper part of the pyramid, on both sides from the emptiness of the Great Gallery, in the massif paired".

Also, I think following my research to be able to make my contribution - "my stone to the building" according to the formula - in the understanding of the mode of construction, namely: "the pyramidal increase" (as I called it) that I extracted, by modeling, the text of the Greek historian Herodotus dating from the fifth century BC. (See: Press Release - Abstract - 2017 (French and English, attached) and thus be able to propose an approach and a research team (Geology, Engineering - Architecture, Know-how of Stone Professions) to analyze internal works of Cheops and articulate a logical, rational and reliable answer to the question posed by the fortuitous discovery of this "great void".

And for these reasons, do I have the honor to solicit, here and now, from Professor Hany Helal, Scientific Director of Mission Scanpyramids, the opportunity to present my research on "The genius of the pyramids" and my integration into the debate team and research program inspired by this discovery.

Prof. Fathi Saleh<sup>37</sup>, Founder of CULTNAT, Thierry Verdel, Thesis Director, Hany Helal, President of the jury of my thesis and Omar Cherif<sup>38</sup>, geologist at NARSS and valuable collaborator, French speaking personalities, are the recipients of this Open Letter to the Mission Scanpyramids addressed to Pr. Hany HELAL and are invited by this mail to represent me and defend this positive and constructive proposal of my interpretation - they all know very well my research - interpretation written, undersigned and recorded<sup>39</sup> this day November 13, 2017.



Pierre CROZAT, 10/11/2017 Architect - Urbanist EPFL (1971); Ph.D./ INPL / Nancy School of Mines (2002)F - 39380 - LA LOYE; [pierre.crozat@free.fr](mailto:pierre.crozat@free.fr); - [http://: www.pierre.crozat.free.fr](http://www.pierre.crozat.free.fr) .

## GENERAL CONCLUSION: the engineering of the pyramids

This scientific, technical and operative research - starting from the details of the tools and of the actual building processes - offers an interactive and predicative model of a construction system, which generates both the concept and the form.

Derived from the primordial domain of the vernacular and from the technical continuum of tumulic structures, and enriched by the tomb constructors' work practice, the construction method of the pyramids belongs to the field of civil engineering, to the know-how of quarry builders. It does not belong to the field of architecture.

The stone materials are borrowed from the perimeter of implantation of the pyramid and are stacked in the center in successive stages of growth, according to a constructive system adapted to the materials in question:

- one such system, is the "accretion - raising" that was used for the step pyramids of the 3rd dynasty: the blocks, dating of the Upper Eocene, which can be carried by hand, are stacked in successive layers 10 ms high. As mentioned, they are found on the site of implantation. The stepsthus created were use of to rest the wood scaffolding. They should therefore be called pyramids built step by step. The pyramids of Abousir, although they belong to the 5th Dynasty (when one knew how to raise "cyclopean" blocks), are built according to the same method, because they are located on a small module deposit of the Upper Eocene.
- the other system is the "pyramidal growth" that was used for the great pyramids of the fourth dynasty. Enormous (cyclopean) 2 t blocks are stacked in successive envelopes, each one nested around the previous one. These blocks are also provided by the sites of implantation of the Middle Eocene. The geological implication and the natural fracturing networks of the rocks (engineering geology) that were shown for the Giza Plateau should also be true on the sites of the two other great pyramids of Dahchour. It needs to be assessed.

This research work, coming from the field of builders, is an objective contribution to Egyptology and archeology. It relies on a theoretical, practical and manual knowledge that is still taught in certain Schools and Institutes, in France and around the world. It shows a technical continuum of the Art of Building. It also corroborates and explains completely Herodotus' writings and his description of the lifting machines made of short pieces of wood.

The SCANPYRAMIDS Project comes at the right time - whatever its purpose, reality and conclusion, it puts the Great Pyramids of Egypt in the media spotlight. I would like to take that opportunity to expose, explain and demonstrate my own research and to demonstrate the logistics and the logic of the builder; starting from the environment, the geology and the natural fracturing of the rocks (geological engineering), the extraction, the dismantling of the blocks in open air quarries situated around the buildings in erection, the transportation of the blocks and the creation of the whole interior devices - the corridors, the chambers and the Great Gallery, that were all built in the open, including the newly discovered Great Void. I wish to demonstrate their usefulness, their perfect realization and functionality, and the intelligence behind it all. The processes engaged by the antique builders are so perfect and logical that it is vain to look for other explanations.

In particular, it seems pointless to invoke the whims of the Pharaoh, the catch-all tradition of errors made by the workers, of defects of construction, and even the frequently invoked symbolism of *"the soul of the Pharaoh ascending to heaven by stairs"*. Equally, such statements as *"the constructive mode of the pyramids was a state secret"* or that *"the secret lies in the stone"* seems irrelevant.

L. Borchardt' theory of three successive projects of chambers: the underground chamber, the Queen's and the King's, in case the Pharaoh died before the completion of the work, does not hold when we shift paradigm by abandoning the construction by horizontal foundations of the "rampist" theories for the "machinist" theory in successive envelopes described by Herodotus, and which I explained in my thesis.

In fact, the first chamber, known as the Queen's, is the beginning of the construction all around it. A small pile of stacked blocks was increased by successive envelopes, then, by anticipation of the construction on the north side, a ramp was built on which they installed an ascending corridor, a large gallery and an upper chamber. The Great Gallery is an "extraordinary oblique lift" to hoist and set up the set of granite (raising system) and limestone monoliths (rafters used to distribute laterally the weight of the upper blocks) above the Great Gallery,



etc. This description is purely of a technical nature: it belongs to the domains of statics and resistance of materials that were perfectly familiar to the builders of that time, an empirical knowledge acquired through experience, accumulated and taught even today in the colleges of the "operational" professions.

All of this device is ingenious, in the true sense of the word. J-Ph. LAUER, architect-archaeologist used the term ingenious in an ironic fashion vis-à-vis Herodotus' machinist theory. Engineering, Civil engineering and Rock Mechanics are fundamental although formalist architects usually do not even consider these domains in their study of the pyramids construction. The whole system is actually so ingenious that it took a tomb violator to force it savagely, with fire (powder from China), vinegar and leverage, said the Caliph Al Ma'mun in 832; that is, 33 centuries later.

Cheops was in his sarcophagus from which Al Ma'moun dislodged him, and Herodotus twice repeated the false declarations of the priests of the Temple of Ptah in Memphis, his informants, who told him the "secret" that had to be constantly brought up, namely that "Cheops is not in but under the pyramid, on an island surrounded by water ». This very effective trickery lasted for 4,500 years and will sure probably last longer....

The pyramid of Cheops has revealed everything except perhaps a technical device for redistributing the charges on both sides of the Great Gallery (my interpretation), which SCANPYRAMIDS has spotted, through the stone, thanks to the muons.

It is probably not the same situation with Chephren's pyramid, which is more recent and built with more regular blocks: it could be even more ingenious. I hope to have the opportunity to participate in its study and to interpret it constructively.

Let us hope that the discovery made by the Scanpyramids team will allow new studies on the building of the pyramids that will rely on observed and scientific bases. Let us hope that non scientific and unproven theories, involving secret chambers, will be put to rest. Let us hope that the world will admire the coherence and the ingenuity of the antique builders who were relying on logical and well mastered techniques, easily understood with geological and engineering approach.

**"If the pyramid of Cheops leaves a little of its Mystery, it gains a lot in Genius"<sup>40</sup> ... "**



*Figure 34: Cheops' pyramid by night (J. Kérisel) showing the thickness (shadow on the edge) of the envelope?*

\* \* \*

## NOTES

---

- <sup>1</sup> - They are dated from the 4th dynasty, under the Ancient Empire. The three great ones are located on the plateau of Giza, near Cairo, the greatest and the most famous "marvel of the world" being Pharaoh Cheops' one (147 m height).
- <sup>2</sup> - Herodotus, Greek historian (5th century BC) - "the Inquiry" - Book II - articles 125 and 126, Gallimard Editions (1964).
- <sup>3</sup> - The "mechanical" theories: trestle of M.Strub-Roessler, lift of L. Croon or the oscillating elevator of G. Legrain.
- <sup>4</sup> - The "ramp" theories: frontal ramp of J-P. Lauer, helicoidally ramp of G. Goyon, lateral ramp of R. Stadelmann or slot-in ramp of D. Arnold, eminent contemporary Egyptologists.
- <sup>5</sup> - Diodore of Sicily, Greek historian (1st century BC) - "Birth of Gods and Men" - Book I- article LXIII - Les belles lettres Editions-La roue à livres Collection (1991) - Translation: M. Casevitz page 77 and 78.
- <sup>6</sup> - The "mixed" theories: represented by J. Kérisel and J-P. Adam.
- <sup>7</sup> - Technological context defined by the previous and contemporary achievements such as the great boat of Cheops.
- <sup>8</sup> - Of course, to model is not to build and virtuality is not reality, however to model allows to conceptualize and to understand. This approach, coming from the Tradition, is used by the Companions of Duty, and is fundamental in stereotomy which permits the apprehension of volume.
- <sup>9</sup> - These blocks serve as padding for the obstruction of the ascending corridor. They were discovered by the sap of Al Ma'moun in 827. Evidently they were in bigger numbers and had first a counterweight function, they were maneuvered many times in the Great Gallery, which explains the presence of this trammel.
- <sup>10</sup> - These monoliths are wrongly considered arches of discharge, whereas only the chevron-patterned superior device has this function.
- <sup>11</sup> - Furthermore the layout of those raising monoliths (made of granite because of its higher bending resistance), far from being a mistake, is lighter filled space combined with empty space than a massif made of limestone.
- <sup>12</sup> - The angle of the pyramid is function of the ratio height/half of the base which equals 1.25 (and not 1.2727 which is the root of the golden section, as it is claimed by some people).
- <sup>13</sup> - Auguste Choisy (1841-1909), son of an architect, French polytechnician, engineer graduated from the Ecole des Ponts et Chaussées, publishes "L'Art de bâtir chez les Egyptiens" (1904)-Edouard Rouveyre, Publisher: "pyramids are built by successively adding layers of stone on the sides of a central "little" pyramid." (p 99). He is the first one to schematize, in an intuitive manner, the building by layers and the onionskin-like structure, without ever demonstrating it.
- <sup>14</sup> - "bomides": small altar, socle, pedestal, elevated platform, table, entablature.
- <sup>15</sup> - "crossai": corbel, crenel forming stairs.
- <sup>16</sup> - remains of quarries that it is impossible to deny and necessary to integrate in any schema of explanation.
- <sup>17</sup> - Sci. Geol. Bull-Researches on the natural fracturing of rock 1969-1972. "Method to study the natural fracturing of rock associated with a variety of structural models" by Michel Ruhland. Research team associated with the CNRS "Structural Geology and tectonic analysis". Institute of Geology at Louis Pasteur University, Strasbourg. Contradicting what can have been said or written by some renown Egyptologists, the three Great pyramids are not located according to the Dog constellation, neither is their orientation determined by the heliacal rise of Sirius. The axis of the fold, determined by the presence of the great faults, is NE-SW, which results in the fact that the diagonal diaclases and therefore the pyramids will be oriented NS and/or EW.
- <sup>18</sup> Pr. Michel RUHLAND, French geologist, L. Pasteur University / Strasbourg.
- <sup>19</sup> - See the aerial photography shot by Marilyn Bridges and published in her book "L'Égypte vue du ciel" p 40. (1996)- Editions du Seuil.
- <sup>20</sup> - It is in fact not surprising to notice that the term "ziggourat" (siqqurat) has a "s.q.r." root which means "to be high" or even "to raise" and that it is the same Hamito-semitic root than "Saqqarah" since it deals with the same shape, could we infer that it also has to do with the same building system? It however needs to be verified.
- <sup>21</sup> - Archeology of the prehistoric buildings "DOLMENS for the DEADS" Roger Joussaume 1985 Editions Hachette. All the dolmens in the world seem to have used this system, most of the time on a more or less mastered circular plan, however the dolmen of la Joselière in Pornic (Loire Atlantique) has the particularity to have been built on a square plan and to have two, maybe three parées, to the extent that it prefigures from a long time the upcoming step-pyramid.
- <sup>22</sup> - Step-pyramid of Djoser in Saqqara is the most famous, it has supposedly been built by architect Imhotep. J-Ph. Lauer has been working for almost 70 years on this site without being able to come up with a satisfactory building explanation. It probably had 7 steps. It is from the analysis of this pyramid that Richard Lepsius will define the "accretion", we suggest the "accretion-raising", since the accretion is only motivated by the will to raise the building. However the correlation suggested by R. Lepsius, between the length of the Pharaoh's reign and the volume of the pyramid keeps whole its value. But it is also possible to consider that more than one king participated in the erection of the same building. This would explain most of the questions raised by the pyramid of Meidum.
- <sup>23</sup> - Georges Ifrah "Universal story of numbers" (1981-1994) Editions Robert Laffont. (p394). The same way, the additional arithmetic learn by Pythagorus from the Egyptians, and that the Greek civilization will later deny and that will later be re- established by the Moderns, who will deduce from it the basics of contemporary Mathematical Theories, is only an adding game of series and sequences fit into each other.
- <sup>24</sup> Suzanne RAYNAUD, French geologist, Montpellier 2 University (France)
- <sup>25</sup> Mark LEHNER, American Egyptologist: "Why has he never thought of superimposing topography and stratigraphy? "

- 
- <sup>26</sup> Pr. Thierry Verdel, Ph.D. In Rock Mechanics, Professor at Ecole des Mines de Nancy, Rector of Senghor University in Alexandria, Advisor of Pierre Crozat's dissertation.
- <sup>27</sup> Pr. Fathi SALEH, Director-Founder Emeritus of CULTNAT Heritage Cultural & Natural of Egypt (digital) knows, follows and appreciates the research work of P. Crozat since 1996.
- <sup>28</sup> - HIP (Heritage - Innovation - Preservation) created in 2015 by three co-founders MMrs. Mr. TAYOUBI, H. HELAL and F. SCHUITEN)
- <sup>29</sup> Pr. Hany HELAL (Dr. in rock mechanics) Pt of my thesis jury), Thierry VERDEL (Dr. in Civil Engineering) Dir. Fathi SALEH, Founder - Director Emeritus of CULTNAT and Omar CHERIF (Dr. in Geology at NARSS).
- <sup>30</sup> Teacher. Hany HELAL, Prof. at the Faculty of Engineering of Cairo University in Giza.
- <sup>31</sup> Pierre Crozat, Ph.D (1941- French) Architect-Urban planner trained at the Swiss Federal Institute of Technology Lausanne (EPFL - Switzerland). SIA Prize (1971), Ph.D at the National Polytechnic Institute of Lorraine - INPL / National School of Mines of Nancy / Laego (2002 , summa cum laude. Thesis entitled "The engineering of the pyramids".
- Other relevant publications : "Constructive System of the Pyramids" Ed. Canevas - 1997 (ISBN 2-88382-064-3 and "The Genius of the Pyramids" Ed. Dervy - 2002 (ISBN 2-84454-161-5)
- <sup>32</sup> Pr. Hany Helal, Ph.D. in Rock Mechanics, Professor at the Faculty of Engineering of Cairo University, former Minister of Higher Education and Research of Egypt, and President of the Ph.D. Jury of Pierre Crozat.
- <sup>33</sup> This "machinist" type of thesis, inspired by the text of Herodotus (fifth century BC) and opposed to "rampist" theories inspired by the text of Diodorus Siculus (first century), is probably the only academic thesis dealing with this method.
- <sup>34</sup> Pr. Thierry Verdel, Ph.D. In Rock Mechanics, Professor at Ecole des Mines de Nancy, Rector of Senghor University in Alexandria, Advisor of Pierre Crozat's dissertation.
- <sup>35</sup> <https://independent.academia.edu/PierreCrozat>
- <sup>36</sup> <http://pyramidales.blogspot.com/eg/search/label/Crozat%20%28Pierre%29>
- <sup>37</sup> Pr. Fathi SALEH, Founder of CULTNAT (Center for Documentation of Cultural and Natural Heritage), former Ambassador to UNESCO, Professor at the Faculty of Engineering of Cairo University, former Cultural Advisor of the Egyptian Embassy in Paris (first person to whom I presented my research in 1998, and who invited me since 2007 to come to give a Conference at CULTNAT on 09/26/2017);
- <sup>38</sup> Pr. Omar CHERIF, geologist emeritus, University of Ain Shams, and the National Authority for Remote Sensing and Space Sciences - NARSS, Cairo / Egypt.
- <sup>39</sup> Deposits for ampliation on the digital sites: Academia.edu and "Pyramidales" by Marc CHARTIER, the date of deposit as proof.
- <sup>40</sup> "Engineering Works & People, Laboratory Environment - Geomechanics and Work - LAEGO, Arts and Crafts, Construction Methods and Know-How, Machinery, Machines and Tools".