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Research Article for online presentation

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TITLE

GEOLOGICAL EVIDENCE FOR AN ALGORITHMIC CONSTRUCTION OF THE GREAT PYRAMIDS

ABSTRACT

We show here that the great pyramids sit in the middle of their respective quarry, their constituent blocks being extracted at their immediate perimeter, as demonstrated by the natural fracturing networks of the rocks and the 3D simulation of the paleo-topo-stratigraphy of the Giza Plateau. Geology also explains their location and orientation.

The proposed pyramidal increase method is to overlay successive envelope cones (in onion peels). The “*wooden machines multiplied and/or moved*” (dixit Herodotus, Vth century BC) allow -simply- to raise and lay a block on two others. This construction method is not in the realm of external geometry (with ramps), but in the realm of internal algorithmic logistics (movement-machine) of labor practice. The final pyramidal volume corresponds to the regularities of pre-Pythagorean geometry.

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TEXT

I. STATE OF THE ART REGARDING ANTERIOR WORKS ON THE CONSTRUCTION MODE OF THE EGYPTIAN PYRAMIDS.

1) Numerous authors have theories on the construction of the great pyramids of Giza, from antiquity to the present days: (according to J-Ph. Lauer)³

a) Mystical theories:

- Biblical theories⁴:
- Theosophical theories⁵:

b) Pseudo scientific theories:

- Astronomical theories⁶:
- Mathematical⁷ theories:

c) Original theories, including:

- Locks :
- Water pressure:
- Artificial stone:

d) Constructivist theories:

Generally speaking, these various theories attempt to propose solutions for the construction (piling of the strata) by men organized in building groups (without involvement of God, of mysteries, of astronomy or mathematics).

Some of them, following Diodorus of Sicily, involve advanced work sometimes larger than the pyramid itself (ramps or locks).

- Frontal ramps⁸: They rely on the mode of transportation of great weights with sleds gliding on ramps made of layers of silt, as shown on Egyptian bas-reliefs. These ramps can be numerous, long and with marked slopes, depending on the authors, and could be raised as the layers of the pyramid are stacked.
- Lateral or enveloping ramps⁹ (external or internal): Based on the principle of ramps put side by side, that get multiplied as the pyramid grows, or of ramps that surround the pyramid, which in turn serves as a support.
- Step pyramids and extra steps¹⁰ to make it smooth¹¹, L. Borchardt (1863-1938): In spite of a formalistic and non-constructive vision that requires an enormous ancillary work, this author's concept of three chambers (subterranean, King's and Queen's) has been considered solid and therefore taken over by numerous Egyptologists without any further proof. ([Fig. S1: The 3 rooms by L. Borchardt](#)).

e) Accretion and lifting machines:

- All preceding works are inspired by the final shape of the pyramids.
- **By contrast, we are interested in the construction method that, in turn, generates the shape.**
- Some authors following Herodotus look for an accretion system and for block lifting machines, without describing, however, a logical constructive process. In addition, they do not determine the origin of the materials (quarries). For example, description of a central core of total height¹² surrounded by walls of decreasing height.

2) We attempted to describe the construction process of the pyramids from the point of view of a builder: seeking solidity, easiness and economy.

By contrast, in this article, we propose a system of algorithmic pyramidal growth¹³: We based our proposal on Herodotus' historical revelations and particularly in a passage in book IV that describes a mode of lifting with wooden machines, and an accretion process based on the movement of the machines. Starting with a primary core, the builders created a succession of enveloping cones made of blocks of local stone

extracted around the building, in horizontal quarries, in successive corresponding volume phases. ([Cf. 1: CV of P. Crozat SEARCHER 2017](#))

We based our work on:

- a) Herodotus (450 BC): his description of the working mode of the machine made of short pieces of wood contains a solution: a real constructive « system » representing a technological and conceptual leap, the final outcome of the technological continuum of funerary tumuli.
- b) Strabo (Ist cent. BC): « *Visiting the pyramids, we observed an extraordinary fact that deserves, we think, to be mentioned. It is a large heap of stone shards that cover the ground in front of the pyramids. One only has to search in these heaps to find small petrifications with the shape and the size of a lentil, resting sometimes on a bed of other debris (petrified as well), that look like half-shelled vegetable peels* » says the Greek geographer, who is interested in the stones of the pyramids and recognizes « lentils » (Eocene limestone: Nummulites of the Lutetian period).
- c) K.R. Lepsius (1810-1884): he was the first to relate the volume of the pyramid and the length of the reign of the pharaoh.
- d) A. Choisy (1841-1909): the author of a « *History of Architecture* » (1899), he studied the construction techniques since Antiquity, including « *The Egyptian art of Building* » (1904)
He had the intuition of a building method via successive envelopes. However, he did not develop and demonstrate the full constructive system, which is what we attempted to do.
- d) M. Serres (1939-2019): historian of sciences and techniques, In « *The origins of geometry* » (Paris 1993) describes a specific pre-pythagorean period of evolution in Egypt that he called « *logistics or algorism* » and which, for us, corresponds to the technological and conceptual leap constituted by the construction period of the five great smooth pyramids. ([Cf. 2: Engineering of pyramids 2017 DIGEST](#))

3) We present a different approach, scientific, technical and operational

- a) our experience as builders cannot admit «rampist theories» of any kind that require far too heavy ancillary work, such as:
 - creating a horizontal platform by clearing a large volume of material (what to do with it, where to place it?),
 - building via "horizontal seating" (increasingly reduced) that requires an annex (ramp) of stone or earth which in the case of the frontal ramp is more important than the future pyramid itself, and which will then have to be dismantled (double work),
- b) Starting from the builder's point of view: as experienced builders, we understood the technical and operational value of the constructive system described by Herodotus.
- c) The technological level of block-picking equipment and the precision of the joints indicate a very advanced (almost contemporary) mastery of the know-how of Stone Trades.
- d) It is the vernacular principle of borrowing the constitutive materials of the work from the immediate surroundings¹⁴, piling them in a conic form, and then keeping building from the center, with enveloping pyramidal cones that create the volume accretion. The pyramid is actually in the middle of its very quarry, with many blocks pre dimensioned by natural fracturation. This interpretation is typical of the technology of the time and belongs to the continuum of tumular works from the Neolithic period.

4) We put in relation the geological characteristics of the site with the construction

Egyptologists and archeologists have not taken under consideration the materials, the geology (structure and stratigraphy), the engineers' geology (study of the natural rock fracturation), the modeling, or the evolution of the constructive method that creates the shape, nor the interaction between the pyramid and its quarry.

- a) M. Lehner and Z. Hawass: In the topographical and geological rendering of the site (Mapping Project on the Giza Plateau, 2005) they have not taken under account the advantages of photogrammetry, nor the importance of geology (structure and stratigraphy), nor the importance of engineering geology (natural process of rock splitting) that we observed on the site at the time. The National Geographical Institute in Paris used photogrammetry as early as the 1960s to create an orthophotoplan of the Giza Plateau.
- b) the step pyramids are constructed with manu-portable stones (small apparatus) supplied by the Superior Eocene deposit of their site and with the constructive "degree" method. ([Fig. S2: Step Pyramids](#))
- c) the photograph of the great excavation of Zaouiet el Arian shows the surface the Upper Eocene layer and, below, the Middle and Lower Eocene layers: although the sarcophagus was installed, this pyramid was never built. Dated to the IVth dynasty (by G. A. Reisner) it belongs rather to the IIIrd dynasty as suggested by its pit and the stratigraphy of the site. ([Fig. S3: Zaouiet el Arian](#))
- d) the great pyramids are constructed with "cyclopean blocks" coming from the Middle Eocene deposit of their site and by the appropriate constructive method of "successive benches » (see further). ([Fig. S4: Great smooth pyramids](#))
- e) The definitive proof is provided by the 3 pyramids of Abousir (degree pyramids with addition of degrees, to make them smooth) which, dated to the Fifth Dynasty (thus after the great pyramids of large apparatus), used the old "degree" method imposed by the Upper Eocene deposit (small apparatus). ([Fig. S5: Abousir pyramids](#))
- f) text pyramids (of the type of Ounas in Saqqarah - VIth dynasty) have become "symbolic", consisting of cyclopean blocks on the periphery (backing stones of the Middle Eocene) and an internal opus incertum of the Upper Eocene). The important part is only the burial chamber with the sarcophagus, the painted starry sky and the Texts of the Pyramid. ([Fig. S6: Text Pyramids](#))
- g) brick pyramids. ([Fig. S7: Brick pyramids](#))
- h) Our analysis is corroborated by the scientific thesis of M. WISSA¹⁵ (1995).
- i) In fact it is the underlying deposit of the pyramid site that imposes the appropriate constructive method. The method, in turn, generates the shape. In other words, the shape of the Pyramids is not a Game of Styles but the result of the Method.
- j) The architectural geometric approach (inherited from the Greeks) has remained inoperative from Diodorus to this day that is for 2500 years, because it was not adapted to buildings made 2200 years earlier.

5) Some archeological proofs that corroborate our vision

- a) The bent pyramid is in the center of its own quarry, as shown by the picture of M. Bridges (*Egypt: Antiquities from above*, Little, Brown and company, Boston. ([Fig. S8: Bent Pyramid](#)).
- b) The 5 Great Pyramids (the rhomboidal pyramid (South Dasher), the red pyramid (North Dasher), and the 3 pyramids of Giza) are made of parallelepiped blocks, arranged as headers, (i.e. their length is perpendicular to the observed face). ([Fig. S9: Arrangement of the blocks "in the back"](#)).

c) The blocks on top of Cheops' pyramid have visible edges that have been disrupted a lot by various demolitions, fractures and renewal. Nevertheless, for each cut block one can see the « horizontal corbelled apparel », the most economical according to A. Choisy. ([Fig. S10: Top of the pyramid of Cheops](#)).

6) By contrast the reasoning presented here corresponds to a deep paradigm shift: it is based on the method, called "system" by HERODOTUS:

Very ancient, it had to be recreated stage by stage as it applied to the pyramid. This system of reasoning, called "Algorithmic Logistics" needs a concrete support.

It necessitates the learning of the theoretical algorithmic path, and its permanent confrontation with concrete and operational reality, and the know-how of stone works. ([Cf. 3: Simulation pyramidal increase - 1997](#))

II. CONSTRUCTIVE SYTEM OF THE PYRAMIDS: AN ALGORITHMIC LOGISTICS (?)

A. INTRODUCTION: THE PRINCIPLE OF THE METHOD

The great pyramids of Egypt are human constructions that belong to the technical continuum of major and minor tumular buildings ([Fig. 1](#)) which, all over the world, are built according to the size and weight of the local materials, and according to the techniques (by hand, with scaffolds, with lifting machines, with elevating engines) available at the time of their erection, or due to circumstances. This analysis explains the evolution of the constructive methods that produce and generate the specific shape of these works. The passage from step pyramids to the great smooth bench pyramids is not just a variation of shape, but the very result of the method chosen.

B. HERODOTUS'S ESSENTIAL CONTRIBUTION

The first historian, Herodotus of Halicarnassus (Vth century BC) described very precisely the operating mode of piling the blocks of Cheops' pyramid, with a system of successive benches (but not steps), called alternately *bomides* or *crossai* (there are several versions). *Bomides* meaning "resting table" and *crossai* meaning "corbel", two complementary, somewhat technical concepts belonging to the domain of construction, that the translators, literary minded Hellenists, did not fully understand and interpret, construction not being part of their skills ([Fig. 2](#)). This description is quite precise and efficient, worthy of development.

Later visitors, heirs of Greek culture, and practicing a geometric vision (Thales already), later Egyptologists, archaeologists and pyramidologists have stumbled on that text and have tried to pierce the mystery of the construction of the pyramids according to the other description, given by Diodorus of Sicily (1st century AD) and mentioning earth levees (ramps) ([Fig. 3](#)), which however represent more work than the pyramid itself, and need to be demolished afterwards. Since that period of antiquity, all kinds of ramp solutions have been proposed, without ever showing plausible proofs, and the solutions invoking machines have remained quasi absent.

C. SCIENTIFIC, TECHNICAL AND OPERATIONAL RESEARCH

The analysis and comprehension of Herodotus' text has opened a new field of inquiry on the construction mode of the pyramids of Egypt, based on three domains:

a) The research on the evolution of the construction methods of tumular works, including the great pyramids of Egypt, belongs to the technical domain of building art.

b) Discovered by an experienced professional, it offers new perspectives, by contrast to the numerous interpretative and personal theories inspired by religious or story telling pretexts. It follows a rigorous path comprising hypothesis, research and development, verification and expertise, experimentation and simulation that is verifiable at every step of the way.

c) It comes from the description of the operating mode of the machine capable of lifting and placing a block from one layer onto the next that the know-how of stone workmanship has in part maintained to this day.

The research presented in this paper is structured in 24 phases of successive hypothesis, according to a logical path based on the logistics of construction, based on personal experience, intuition, observation, study, comprehension that started in 1990 in front of the Sphinx, with a challenge to the construction professional: "how would I build a pyramid?".

- 1) Hypothesis of the principles of vernacular techniques and effort saving: one builds with materials taken from the immediate surroundings, hence the choice of a site capable of providing them and according to the available technique.
- 2) Hypothesis of the "sand castle": how to create a big heap? Start with a small one and find how to increase its size [\(Fig. 4\)](#).
- 3) Hypothesis of construction with stairs¹⁶, then research and analysis of Herodotus' text followed by hand drawn, then infographic modeling of the piling [\(Fig. 5\)](#) (see the [infographic animation in the annex](#)). Development of the system of "pyramidal accretion", with stacked envelope-cones and demonstration of the utilitarian role of the great gallery [\(Fig. 6\)](#) in Cheops' pyramid: an extraordinary oblique lifting ramp, capable of hoisting to their destination the 50 granite monoliths of the King's chamber, on a cluster of inclined surfaces created by the system itself. Thus, the most enigmatic pyramid is the most revealing of the constructive system of the great pyramids¹⁷ of Egypt.

D. THE PART OF GEOLOGY

- 4) Application of the old vernacular principle, i.e. borrowing the materials from the very surroundings of the construction erected in the center, via successive corresponding phases: the pyramid is therefore in the middle of its quarry site, at every stage, which implies the geological and petrographical study of the erecting site.
- 5) Study of the geological characteristics of the Giza plateau (origins, structure, stratigraphy, karstic erosion) showing that the Giza plateau is an anticline fold with an NE/SO (axis, North 45°) with two networks of discontinuities¹⁸: the main one made of parallel and transversal joints and the secondary one, diagonal to the previous one (alpha delta right and left [\(Fig.7\)](#)). This framework of diagonal (closed) joints dictates the orientation of the exploitation of the horizontal and slope quarries, today as well as yesterday, and therefore the orientation of the pyramids themselves. The three Giza pyramids are thus oriented by geology¹⁹. As a proof, striated tectoglyphs oriented E/W were discovered on the North face of the rock bed of Chephren's pyramid in 2005 [\(Fig. 8\)](#).
- 6) The Sphinx is a quarry leftover (the plateau was dug all around it [\(Fig. 9\)](#) where one can read the stratigraphy²⁰ and the slope of the plateau [\(Fig. 10\)](#). Its head belongs to the same (a) layer (Auversian) than the second story of Khentkawes' tomb and the high temple of Chephren. Chephren's pyramid borrowed its materials from a single stratigraphic layer called (g) "building stone", that provided good quality stone, 12 meters in thickness, dense and easy to exploit.
- 7) The 3D simulation (GoCAD)²¹ of the paleo-topo-stratigraphy of the Giza plateau with the orthophotoplan²² as a background constitutes a novel approach [\(Fig. 11\)](#). It made it possible to situate all three pyramids within the stratigraphy: Mykerinos' at level 75m; Chephren's at level 70m; Cheops' at level 60m [\(Fig. 12\)](#). Each pyramid used deeper and deeper geological layers, with different levels of hardness and density, which explains their various states of conservation.
- 8) Chephren's pyramid being built with the single (g) layer of building stone, quite dense but a little fragile, presents a great regularity at its base, and in its blocks and their assembly, but also a strong erosion [\(Fig. 13\)](#) noticeable on several of the envelope-cones.

This type of erosion does not exist on Cheops' pyramid, because its envelope-cones came from lower (f) layer at 4m, and (e) layer at 5m and a portion of (d), that are much less regular but much more resistant to erosion. Only the final cover is in limestone from Tura, on the left bank of the Nile, and it disappeared because of erosion and human carrying, as did Chephren's, in part only.

9) In Cheops's pyramid, the Queen's chamber appears situated on the pre-existing plateau²³, at the center and at the beginning of the construction of the pyramid, and at the center and the beginning of the sub-horizontal peripheral quarries, as indicated by the median cut (N/S), despite a slope NW/SE of about 3,2%.

E. THE VOIDS DISCOVERED BY SCAN PYRAMIDS MISSION OF 2017

10) The existence of the great and small voids in Cheops' pyramid, discovered by the Scan Pyramids²⁴ mission has not so far been explained by Egyptologists²⁵[\(Fig. 14\)](#).

By contrast, research on the construction mode of the pyramids allows a cautious interpretation²⁶, based on statics and stone resistance: the voids could represent a protection system for the great gallery and the ascending corridor that had to remain functional until the entombing of the king at least, while the pyramid was only half built.

11) This cautious interpretation suggests that it is a relief duct, placed over the fragile great gallery and the ascending corridor, to protect them. This duct consists of horizontal bushels made of rafters [\(Fig. 15\)](#), whose static role would be to distribute the charge (of the future pyramid not yet constructed) on each side of the body already built. An image of this cautious charge distribution system can be seen on the North face, with the two overlapping rafters above the entrance -the outcome of this Chimney of discharge[\(Fig. 16\)](#), which show the combinatory organization of the overlapping bushels on the slope.

12) The existence of the voids revived our constructivist approach. Indeed, the use of "*a machine made of short pieces of wood*" for lifting (a lever on a tripod called Chadouf in Egypt), whose machine motion constitutes an algorithm: a simple concrete physical lifting algorithm, consisting of lifting one block to place it on two others, with a necessary foothold to achieve the action (as described 24 centuries later by Archimedes). Our research developed this vision as early as 1996 ²⁷. This approach takes under account the coordinated use of the quarry and the erection of the pyramid, as well as the simultaneous achievement of the inner arrangements of the pyramid. Particularly the poorly named "girdlestones" that are successive abutments whose role is to block the great gallery and prevent it from slipping, since its floor blocks are arranged on a slope rather than horizontally.[\(Cf.4: Open letter to Scanpyramids\)](#)

F. MODULAR COORDINATION

13) It made necessary the research of a modular coordination and a progression rhythm P./Q. (Pyramid/Quarry). We used a theoretical design with a square plan where the center, common focus of both the pyramid and the quarry for each phase of accretion, is at level (0), on the pre-existing ground, and the top at level (6); the extraction floor is at level (-1), generating a volumic pyramidal accretion, with a ratio of 7, whether in plan or in elevation, whatever the ratio between the height and the half base ²⁸[\(Fig. 17\)](#).

G. ALGORITHMIC HYPOTHESIS

14) This algorithmic hypothesis compares quite favorably with the surveys of Maragioglio& Rinaldi (1965) and of Dormion (1996) and with the stratigraphic data [\(Fig. 18\)](#):

- a) The queen's chamber is situated on layer (g) (12m) at 21m (level (0)).
- b) The ascending corridor cuts through the limits of layers (g) (12m) and (f) (4-5 m) at the very spot where the "local stone block" appears;
- c) It descends through this layer (f) (4-5m) to its limit with the sub layer (e) (also 4-5m), where it joins the descending corridor that goes through that layer and through the following one (d) (also at 5m), etc. The limit between (c) and (d) corresponds to the butt of the built masonry so called "thieves passage", at the bottom of the grotto that

marks the final level of taking from the quarry and the beginning of built blocks at the foot of the pyramid.

- d) One finds the layer of pebbles in which the grotto was dug on the slope, above, at the foot of the G 2000 Mastaba, cleared away by the slope quarry.
- e) Al-Ma'moun sapping was dug at the bottom of layer (f) (4-5m); its horizontal floor belongs to the inferior layer (e) (5m).

15) The double concept of "Logistique ou Algorisme" (M.SERRES²⁹, 1993) confirms the ensemble of the mechanistic solution. It was in use at the time of the construction of the great pyramids and played a major part in the appearance of geometry in Greece, 2000 years later. The metrics of ancient Egyptians was misunderstood and rejected by the Greeks³⁰.

H. CHEOPS' CUBIT

16) Egyptologists³¹ have determined a measure unit to apply to the pyramids, called cubit. But at the theoretical level, both the size of the unit and the ratio between the height and the base of the pyramid have no influence whatsoever on what generates the pyramidal accretion. The accretion depends only on the plan, and on the algorithmic interplay established by the ancient surveyors (Harpedonapts, or string stretchers). Such an algorithmic construction logistics is necessary for any building at any time. It is obvious in all three great pyramids, and particularly Chephren's (Fig. 19).

One must examine the rules of stone professionals³² (quarry workers, cutters, positioners, etc) to understand the process. One must also examine the orientation of the stone extraction depending on the diagonal network, the depth and width of anthropometric trenches, the technical ways to detach the blocks, the cutting of the stone base into the blocks, etc., as demonstrated by the traces left in situ. These operational practices are still in use nowadays in the last manual stone quarries in Egypt (Fig. 20).

17) To summarize, the ramp solutions are all based on the posterior geometric vision inherited from the Greeks. But the pyramids were built by the anterior know how, that we call algorithmic logistics, and represent its concrete demonstration³³.

I. PHOTOGRAPHY & COMMENTARY by Z. HAWASS

18) The aerial photographs of Chephren's pyramid (M. Bertinetti) published by NGS³⁴ and by WhiteStar³⁵ are all very interesting, but the most revealing (Fig. 21) deserves particular attention³⁶ because of the accompanying commentary (p.59): **"Summit of Chephren's pyramid in fine limestone from Tura. The supporting masonry appears regular here, under the facing, but the depth of the blocks and of the steps varies considerably. The fragments of the supporting masonry adhere to the core lower, after removal of the facing"**.

This statement does not take under account the natural disintegration of the limestone blocks by erosion. Also, the term "supporting masonry" does not correspond to 99% of the volume of the pyramid: it constitutes and generates its shape. This formalist vision concentrates on the surface and does not understand that the fragments are caused by the sliding of the eroded enveloping cones, clearing the one that is being observed: one can see four of five of them on a photograph of the ensemble, counting their projecting shadows (Fig. 13). Under this enveloping cone called, here "supporting masonry" there exist many others starting at the core of the pyramid³⁷.

The 3D simulation of the Gizeh Plateau paleo-topo-stratigraphy explains the regularity and the normalization of the blocks of Chephren's pyramid. They were only taken from the (g) layer, i.e. "building stone", to the exclusion of any other layer (Fig. 10). This geologically based observation leads to others of the same type, that explain, in turn the irregularity of Cheops' pyramid blocks, taken from the underlying (f) and (e) layers and the presence of a very regular core at the heart of the Cheops pyramid, precisely where all the inner devices are (Queen and King's chambers, ascending corridors, great gallery and relief chimney). The algorithmic regularity allows quite precisely their execution.

In the same manner, stratigraphy explains the quality and the color of Mykerinos' pyramid and of the second level of KhentKawes' tomb, as well as the Sphinx head and the top of the massifs of the high temple of Chephren, all coming from the Auversian(a) layer (partial « on-lap » surface of the plateau).

Chephren's pyramid is more perfect than his father's Cheops. The construction minded analyst finds it strange that Egyptologists consider it the most simplistic, and we think that when it is submitted to muography, a new discovery will be made.

19) One sees a fundamental difference between commentaries focusing on the surface of the pyramids and the study "from the inside" summarized here. The constructor's approach is necessary and gives way to new solutions. It should be taken under account and debated at the world level of scientific culture and technique. An international expertise could be led, independently from the current protagonists, since the Egyptian pyramids belong to the World Heritage, to the history of civilization, to the history of construction (geology, engineering, civilian engineering, mines and quarries), to the history of science and of mathematics.

20) The pyramid sits at the center of its quarry: the vernacular principle (P. Crozat, 1997) consisting of borrowing from the immediate surroundings to pile and amass in the center was corroborated by the paleo-topo-stratigraphy simulation. Additional studies are needed on the dimensional and quantitative coordination of the blocks through each phase of the pyramidal accretion. Also, one needs a modular coordination of the correspondence Pyramid/Quarry.

One should seek the surfaces and depths of the quarry, except for the extraction trenches, that correspond to the volume and number of the examined enveloping cones. Theoretically, they should represent a geometric, volume progression, to reach the final phase of the pyramid before its cleaning, the cleaning consisting of breaking the edges of the steps of the last enveloping cone made of fine limestone from Tura: "*the pyramid was finished starting with the top and the lower benches (not steps) until the base of the building*", says Herodotus. The pyramid is finally completed and "dead" since there is no more support for the *crossai* blocks to be put.

J. ALGORITHMIC LOGISTICS THEORETICAL MODEL

21) The solution proposed by this research on the modular coordination between the pyramid and the quarry is based on a network of extraction trenches with a width of a « royal » cubit (the width of the quarry worker) isolating square blocks of 6 cubits in both directions of the secondary diagonal network created by the natural fracturation of the rocks (see above part 5) geological hypothesis). The network is diagonal with respect to the NE/SW axis of the anticlinal fold of the Giza plateau, i.e. N/S and E/W:

- a) This provides 6 blocks of 2x3 cubits for each face of the pyramid, also oriented N-S-E-W. The axial design of this square network of trenches is therefore 7 cubits. The theoretical growth rhythm proposed here is of one "negative" (1n) extraction bed in the quarry providing the blocks (2x3 cubits) necessary for piling six "positive" (6p) beds built "in charge pile", that is, a pseudo symmetrical triangular piling, as defined by the construction system shown.
- b) The ensemble of the construction processes in this way for each enveloping cone fitting over the preceding one: 2 negative beds providing the necessary blocks for piling 12 positive ones, then 3 negative ones for 18 positive ones, etc. ([Fig. 22](#)).
- c) The "theoretical" research of "algorism" (step by step) drawing on the concrete extraction of Quar. blocks ([Fig. 23](#)) requests coordination with the "pile-up" stacking of the Pyr. blocks. These blocks are pseudo-normalized because they are imposed by the manual extraction mode (and by the trench grid) and the limited handling-transport mode (at the most economical). It requires the relearning of this mode of reasoning or constructive logic dictated by the algorithm provided by the "machine-motion" which imposes its rigorous logistics ([Fig. 24](#)).

d) In fine, whatever the height of the layers, the blocks must be extracted, moved and installed manually, through the multiplication $[1n \text{ (negative)} + 6p \text{ (positive)} = 7]$ of the proposed pyramidal accretion. Each of the enveloping cones, at the end, will always be 7 times the height of its quarry, even if the sitting benches are not very regular; hence the necessity-invention of a horizontal assembling with recesses³⁸, that one can observe everywhere.

22) The most striking moment in the checking part of this research consisted (Fig. 25) of over imposing drawings of the inner arrangements (according to DORMION's renderings, 1996) with the colored drawings of the strata of the quarry (colored to follow easily the logistics imposed by the algorithm, on a N-S section of Cheops pyramid, at a scale of 1/200th - 5 mm/meter). One can then see that the ensemble of the inner arrangements (King's and Queen's chambers, ascending corridor, great gallery and relief chimney) and the ventilation ducts come under the same algorithmic logistics proposed by the builders. In addition, the stopping of the ventilation ducts of the Queen's chamber, 63m from the center, could correspond to an accretion phase of the Cheops' pyramid of a different origin (borrowing from the West at level (g) building stone).

In this first regular inner pyramid, we were able to model in details the progression of pyramidal growth that creates the access way to the two symmetrical voussoirs of each rafter constituting the plugs of the « careful » discharge chimney over the great gallery. Therefore, we propose a second use, their simultaneous erection, for the « extraordinary slanted elevator », whose primary function is to put in place the King's chamber monolith.

K. COMBINATORIAL OF TWO ALGORITHMS

23) M. Bertinetti's photographs are always of great quality, but they are also of great interest for our thesis, for they allow a detailed, in depth analysis. The one showing the top of Chephren's pyramid was colorized by us for better understanding. It shows a new algorithm for the covering, ignored up to now, that combines with the construction algorithm of the pyramidal accretion modelised since 1997.

The difference between these two algorithms is the following (Fig. 26): for the construction, the blocks were placed as headers, while for the covering they were placed as stretchers, which allow the crossing of the angular blocks on the edges, from one bench to the other. This archeological observation, available to all nowadays, involves definitively the solution of algorithmic logistics for the great pyramids.

L. CONSTRUCTION'S SIMULATION - 2019

24) Following the various partial simulations already carried out (1996, 2001 and 2005, into P. CROZAT's web site <http://pierre.crozat.free.fr>), the movie simulation of the construction of Cheops' great pyramid is now almost completed (Fig. 28). However, it necessitates competency, collaboration, technical, logistical and financial means to be achieved. The system of pyramidal accretion that was developed, beginning with Herodotus' text, engage the domain of algorithmic logistics and corresponds perfectly to the concept of self-regulating system developed by Edgar Morin³⁹. It should be taken under account and debated.

M. CONCLUSION

To conclude this communication on the constructive system of the pyramids, there is nothing sacred, mysterious or irrational there. Also, it is not "geometry", which appeared in Greece 2000 years later, contrary to what is commonly claimed. It is "an appropriate system" (Fig. 27) based on Algorithmic Logistics, the existence of which at the time of the pyramids was authenticated by Michel Serres -1993).

So far, no one had taken geology under account: genesis, structure, stratigraphic, and **Engineer's geology** (networks of natural fracturation of the rocks) although it is what explains rationally the positioning and the orientation of the three great pyramids of Gizeh; nor had the quarry extraction method in sub horizontal layers been studied, nor its

clear traces, observable by everybody and nor had the evolution of the method used within the Technical Continuum of tumular edifices been discussed.

Purely external observations of the shape of the pyramids cannot possibly clarify the fact that the shape of the pyramid is the very expression of the method used, itself adapted to the size and weight of the local material provided by the immediate surroundings, hence the choice of an adequate site.
[\(Cf. 5: Lettrecirculaire à mes Pairs 2018 -in french\)](#)

In fine, beyond time, space, and civilization difference, let us observe this photograph of the digging of a channel, by hand, in PRC, at the time of the Mao Zedong's Cultural Revolution, for social re-adaptation ([Fig. 29](#)). It is the archaic technique that interests us, the only usable one in the absence of mechanical engines. Without contest, it goes back to the first agrarian civilizations of the great rivers (Igharghar, Triton, Indus, Tigris and Euphrates, Nile, Huang HO, etc.) and to the hydrological works to control the swelling waters and irrigation, primordial structuring features of the constitution of the first States. For our thesis, it represents a fine illustration of the Algorithmic Logistics, although spatially reversed vis à vis the pyramids. Thus, in Shaanxi province around 2300 BP numerous earth pyramids were erected (tombs) where one can see where the material was taken from, around them. It represents an « ontological » direct link between quarry and pyramid. ([Fig. S11: Pyramids of Shaanxi-PRC](#)).

* * *

ACKNOWLEDGMENTS

Without the precious assistance of my friends, this communication could not have happened:

Ms. Soroor Ghanimati, Ph.D., architect and archeologist at NES/UC-Berkeley, USA, for following my research and suggesting publishing,
Ms. Brigitte Berthier, Information Technology professor, Lycée Pasteur in Dole, France,
M. Bruno Hostalery, engineer ESTP- Paris, France, Infographist and programmer, Lausanne, Switzerland,
M. Patrick Faivre, DPLG architect, for his help with document research, in Lyon, France,
Ms. Françoise Zurif, Ph.D, for translating and providing scientific redaction advice, La Loye, France.

List of Supplementary Materials

1) **References only cited in the SM:**(Cf.#).

Cf.1:[CV of P. Crozat SEARCHER 2017](#)

Cf.2:[Engineering of pyramids 2017 DIGEST](#)

Cf.3:[Simulation pyramidal increase- 1997](#)

Cf.4:[Open letter to Scanpyramids](#)

Cf.5:[Lettre circulaire à mes Pairs 2018 - in french](#)

2) **Publications:** Publications produced as this research progressed have been filed or/and published, the following non-exhaustive list:

- « SYSTEME CONSTRUCTIF DES PYRAMIDES » 1996-97 - Ed. Canevas (F) et (CH) - ISBN 2-88382-064-3
- « *Le Génie des Pyramides* » 2002 - Ed. DERVY - Les lieux de la tradition - Paris - ISBN 2-84454-161-5
- Publication of the Doctoral Thesis "*Le génie des pyramides*" supported in 2002 in Civil Engineering.

3) **Reviews and Deposition Sites for Researchers:**

- POUR LA SCIENCE, édition française de SCIENTIFIC AMERICAN, no 265 novembre 1999, rubrique Perspectives Scientifiques, page 14, intitulé : « *Rampes ou enveloppes ? : de nouvelles hypothèses remettent en cause l'utilisation des rampes pour la construction des pyramides d'Egypte* ».
- Journal officiel de la National Geographic Society, vol. 2.4, no 7, avril 2000, rubrique GEOGRAPHICA, intitulé : « *NOUVELLES HYPOTHESES SUR LA CONSTRUCTION DES PYRAMIDES EGYPTIENNES* » par Anne Hebert.
- *SYSTEME CONSTRUCTIF DES PYRAMIDES* : de la géologie à l'édification (P. CROZAT et Th. VERDEL) 2002 /JNGG et ResearchGate.
- « *Les grandes pyramides* », Ed. Publi-Topex / Ordre des Géomètres - Experts, revue « mesure & grands chantiers - 4000 ans d'histoire - 2002.Revue du Palais de la découverte - Paris : DÉCOUVERTE N°343 DÉCEMBRE 2006 - Article de P. CROZAT intitulée « *le génie des pyramides* »- 2006.
- Journal de l'Association Ouvrière des Compagnons du Devoir du Tour de France - AOCDTF / Paris.

4) **Depositions on: Academia.edu-ResearchGate- Pyramidales**

- Diaporama Espace des Sciences de Paris
- Animation Pyramide
- CV PC CHERCHEUR
- CV- PC SEARCHER
- Abstract 2017
- COMMUNIQUE 2017
- Digital invitation CULTNAT
- Engineering of Pyramids (digest)
- Le Génie des Pyramides
- OPEN LETTER
- LETTRE OUVERTE Def.
- Lettre Circulaire à mes Pairs - in french
- COMMUNIQUE 2019

5) <http://www.pierre.crozat.free.fr>

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Fig. 1: Photograph of the Maes Howe tumulus of the ORKNEY ISLANDS (ORCADES)

The Maes Howe tumulus is more than 20 feet high and 100 feet in diameter. It dates from the Neolithic period (-5000 BP). It is the most expressive prototype of the "vernacular" method: exploiting around the edge to pile up in the center. (Ed. NATIONAL GEOGRAPHIC - August 2014).



ILLUSTRATION OF THE VERNACULAR PRINCIPLE OF SAND CASTLE INCREASE
(like a child on the beach)

All the world's tumular works retain this same principle regardless of their constructive method, up to and including Egypt's great pyramids.

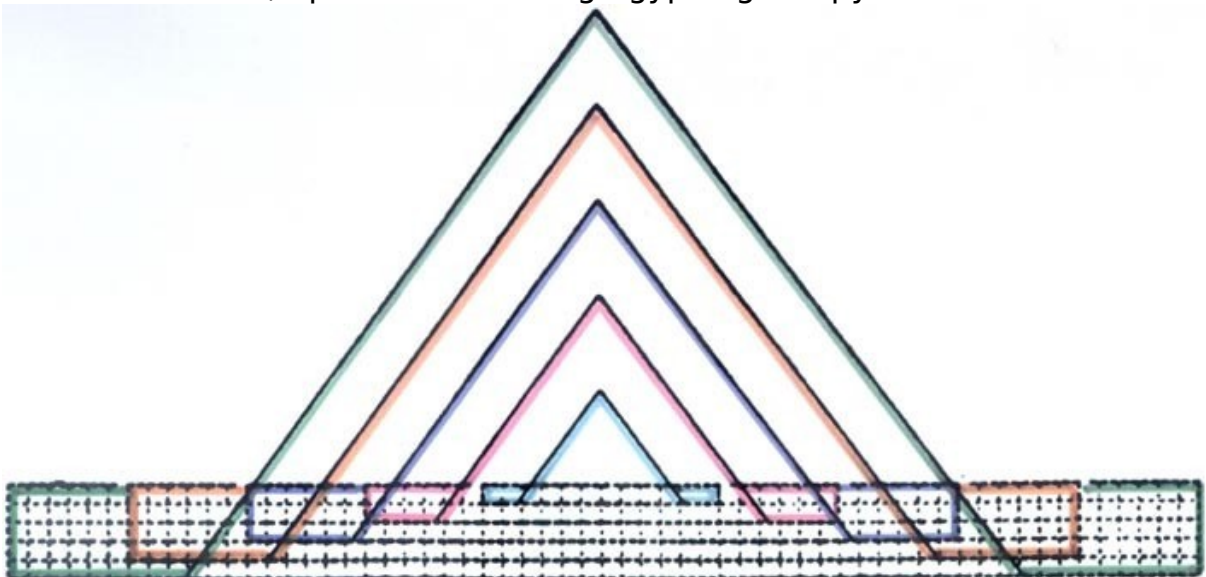


Diagram of the cut of the pyramid of Cheops

Construction in successive phases of cones piled up on top of one another, coming from corresponding borrowings in horizontal quarries situated at the very feet of the pyramid.

THE PYRAMID IS BUILT IN CENTER OF ITS QUARRY.

**Fig. 2: Texts of Diodorus of Sicily (-50 BC) and Herodotus of Halicarnassus (- 450 BC)
on the construction of the Pyramid of Cheops: comparative and explanatory study**

Herodotus ou Diodorus of Sicily

Text of Diodorus of Sicily, Birth of Gods and Men, Book I - 63 (- 50 BC)

"It is said that the stone was imported from Arabia, from afar, and that the setting used earthwork, for the machines had not yet been invented at that time; and the most admirable is that, while works of this importance have been built and the country that contains them is all sandy, there is no trace of earthwork or stone-cut, so that the construction seems not having been produced, step by step, by human work, but deposited from a single block as by a god in the sand that surrounds it. Some begin to tell wonders about this, claiming that the levees were composed of salts and niter, that the river has reached and dissolved them and that their disappearance is its work without it being the result of human activity. The truth is certainly not there, it is by the multitude of arms that have put down the lifts that the whole work has been restored to its primitive state, the fact is that three hundred and sixty thousand men, it is said, were occupied to carry the work and that the whole of the construction was barely completed after twenty years"

Text of Herodotus, The Investigation, Book II, 124-125 (-450 BC)

"This is how this pyramid was built, by the system of successive benches, "**sometimes**" called krossai (corbels), "**sometimes**" bomides (platforms). It was first built in this form, then the complement stones were hoisted with machines made of short pieces of wood: the stone was raised from the ground to the first platform; there, it was placed in another machine installed on the first bench, and pulled it to the second bench, where a third machine took it. There were as many machines as there were benches, unless there was only one easy to move that was transported from one bench to another, as soon as it was unloaded (this to indicate the two processes that tradition reports). So we finished first at the top of the pyramid, then the floors below, one after the other, and ended up at the lower benches and the base of the building».

According to the Bailly's Dictionary

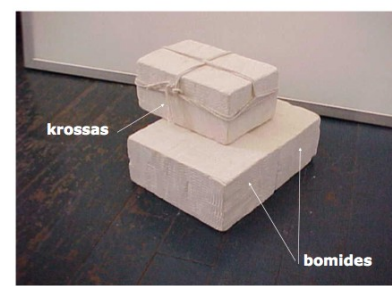
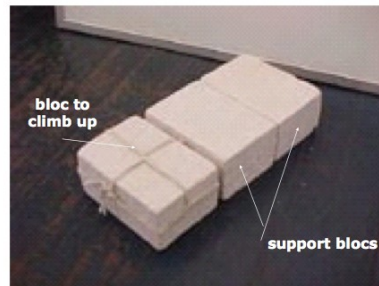
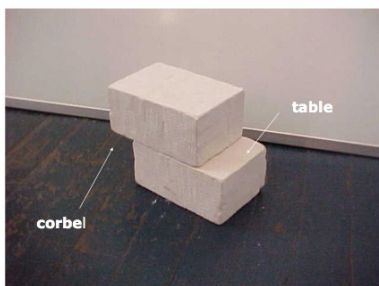
"**bômides**": originally small altar, by extension pedestal, high platform, **table (support stone on which to lay something)**

"**krossai**": **CORBELS (protruding stones)**

"**sometimes - sometimes**" = **alternating denomination during construction depending on the role of the block**

In fact all the blocks are called "**krossai**" when they climb up and make stairs, they become "**bômides**" when they are sitting in their place, and are used to support the next "**krossas**".

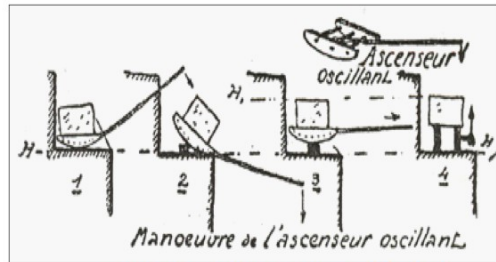
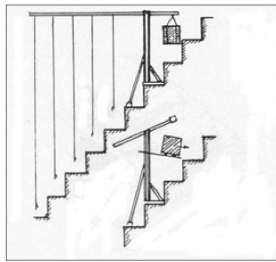
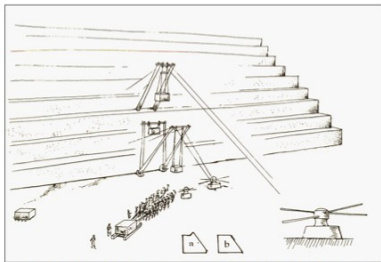
THIS "CONSTRUCTIVE SYSTEM" IS SIMPLE, purely ADDITIONAL, REPETITIVE, RECURRENT: "**a niche forming staircase**" (Bailly)



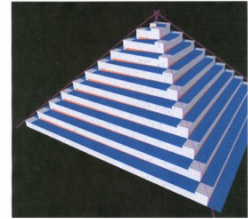
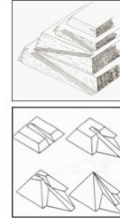
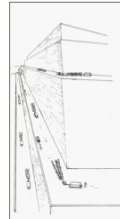
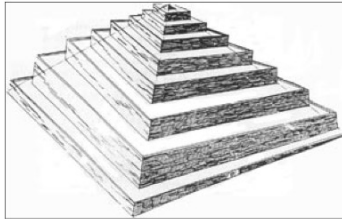
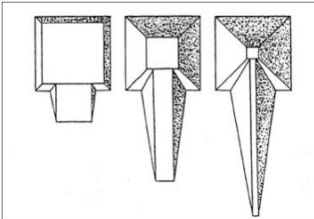
Bômides below, krossas above: one mounts a krossas block on two bômides blocks = the algorithm.

Fig. 3: Illustrations of the different "rampist" and "machinist" theories

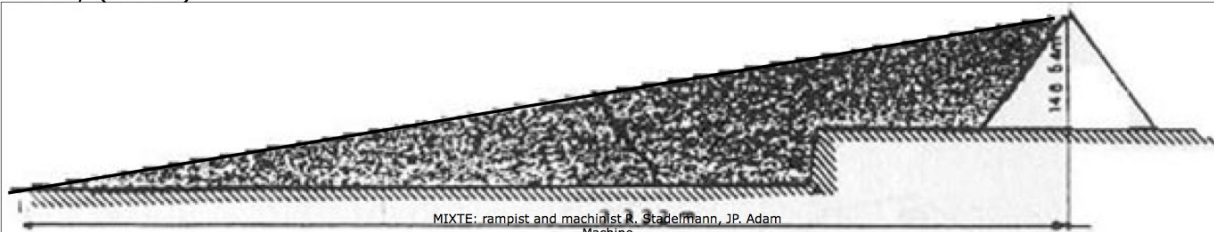
The various constructive « theories »



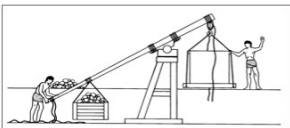
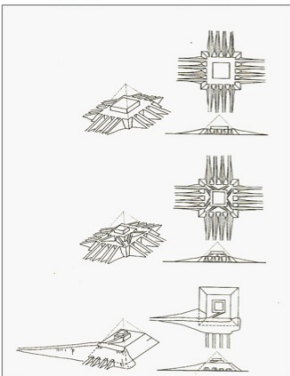
MACHINISTS: trestle (Straub-Roessler... ..elevator (Croon,) oscillating lift (Legrain et Choisy)



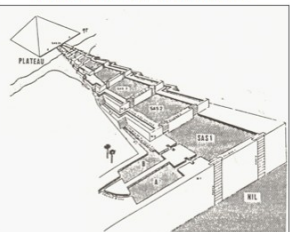
RAMPISTS: frontal ramp (J-Ph. Lauer), helicoidal (G. Goyon), zigzag (Hampigian), ramp engaged (D. Arnold), built-in, i(JP Petit)



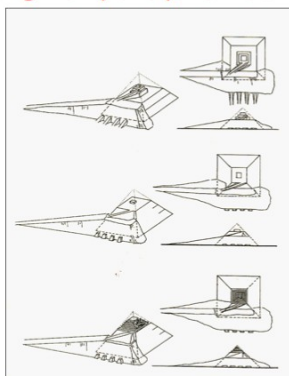
Problem : The "earth-raising" ramps require much more work (and demolition) than the pyramid itself



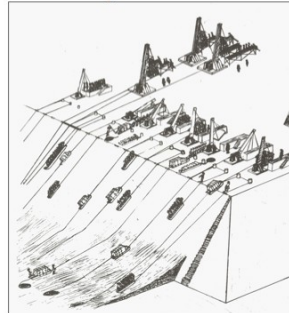
Machine of JP. Adam



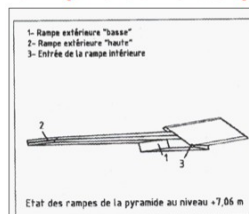
locks (Mingez);



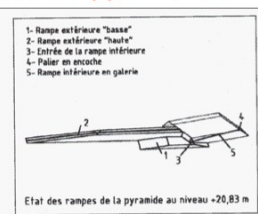
MIXTE: rampist and machinist (R. Stadelmann, JP. Adam)



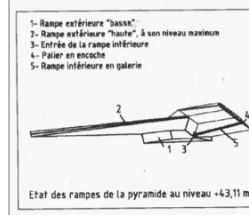
sleds (L. Albertelli);



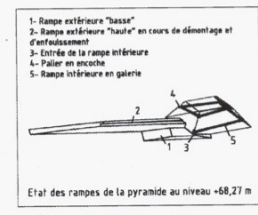
Etat des rampes de la pyramide au niveau +7,06 m



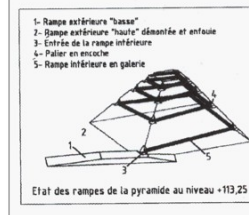
Etat des rampes de la pyramide au niveau +20,83 m



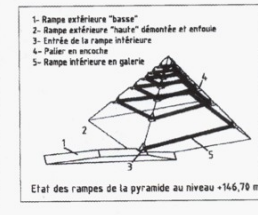
Etat des rampes de la pyramide au niveau +43,11 m



Etat des rampes de la pyramide au niveau +68,27 m



Etat des rampes de la pyramide au niveau +113,25 m

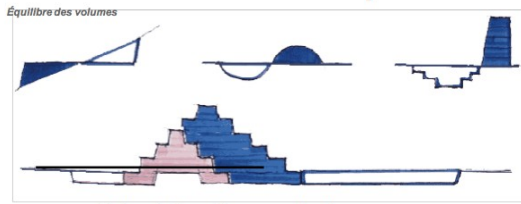


Etat des rampes de la pyramide au niveau +146,70 m

straight ramp and inner helicoidal ram(J-P. & H. Houdin)

Fig. 4: Development of the Machinist System: Pyramidal Growth by P. CROZAT (1997)

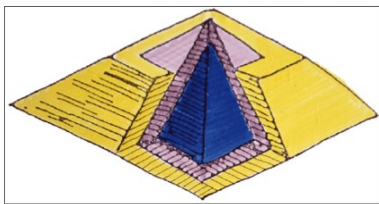
Pyramidal growth system



Principle of mass balance

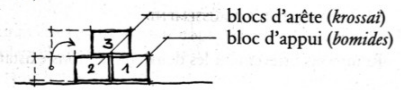
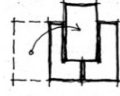


Sand castle : borrowing from around to stack in the center



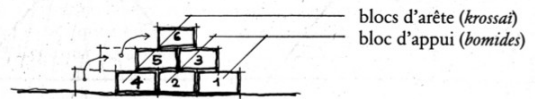
Growth scheme of A. Choisy

en plan

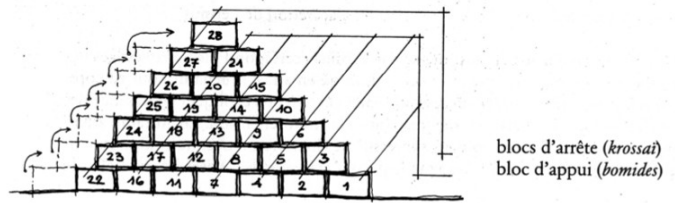


blocs d'arête (*krossai*)
bloc d'appui (*bomides*)

Mouvement élémentaire d'exhaussement

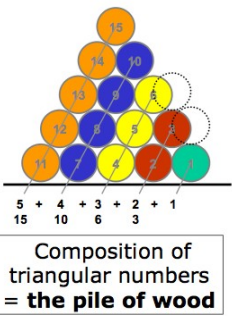
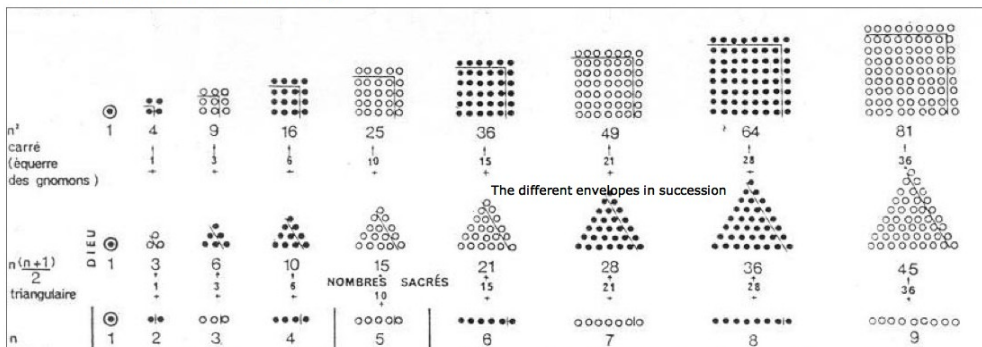


blocs d'arête (*krossai*)
bloc d'appui (*bomides*)

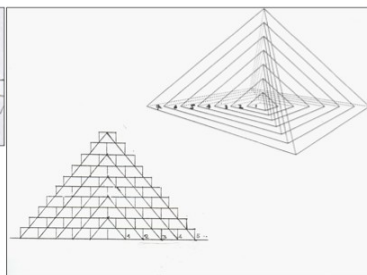
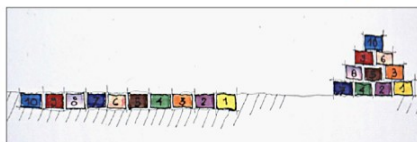


blocs d'arête (*krossai*)
bloc d'appui (*bomides*)

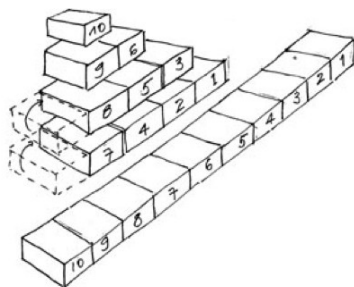
Block stacking order : *krossai* become *bomides*



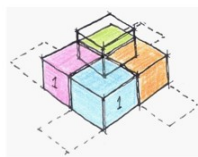
Series of so-called "sacred" figure numbers of PYTHAGORE : linear, triangular, square... Etc...



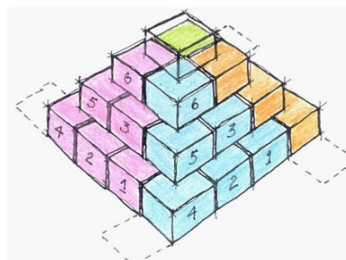
The different envelopes in succession interlocked on top of each other



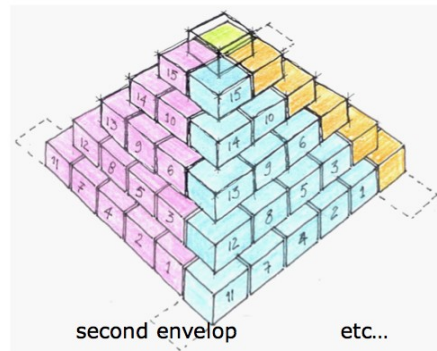
Block stacking order



Minimum pyramid



first envelop

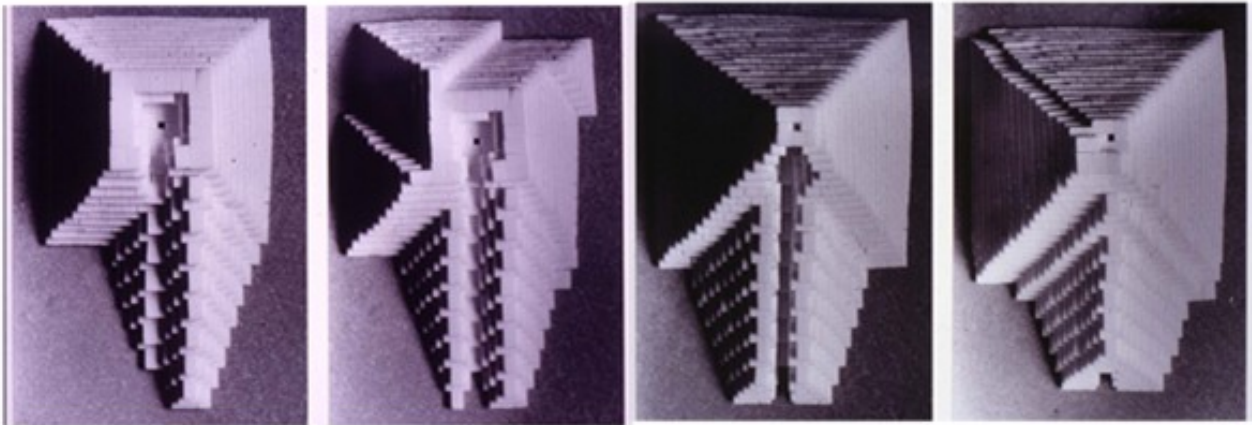


second envelop

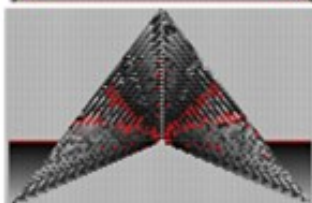
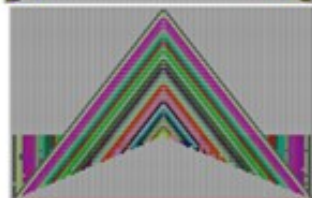
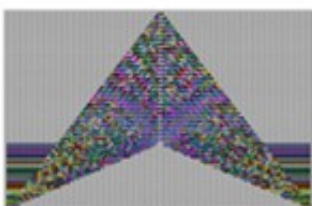
etc...

Fig. 5: Manual and successive computer models of the pyramidal increase.

MODELLING: ANTICIPATING TILTED PLANES

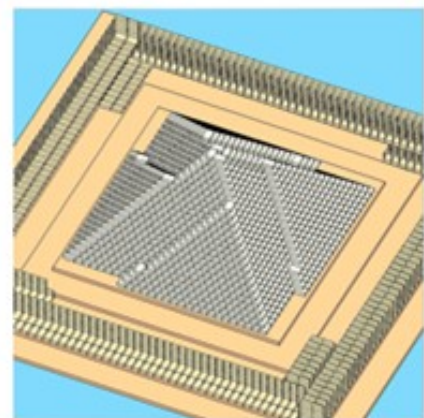
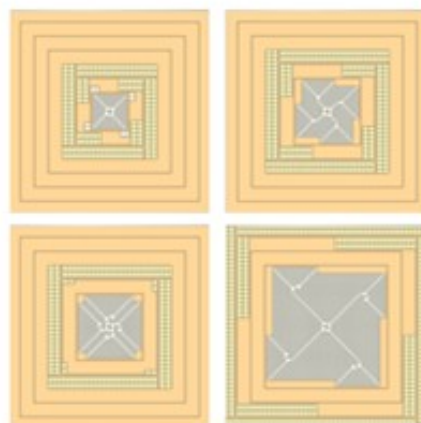


First experiment - modelling with pieces of sugare



Artificial intelligence

Infographic model
(B. Hostalery & P. Crozat - 1997)



Computer Simulation: Pyramid on his Quarry : S. Hensgen ENSMN 2005

Fig. 6: The utilitarian role of the Great Gallery of the pyramid of Cheops as "an extraordinary oblique lift" capable of hoisting the 54 monoliths of the King's Chamber

Pyramid of Cheops: Great Gallery

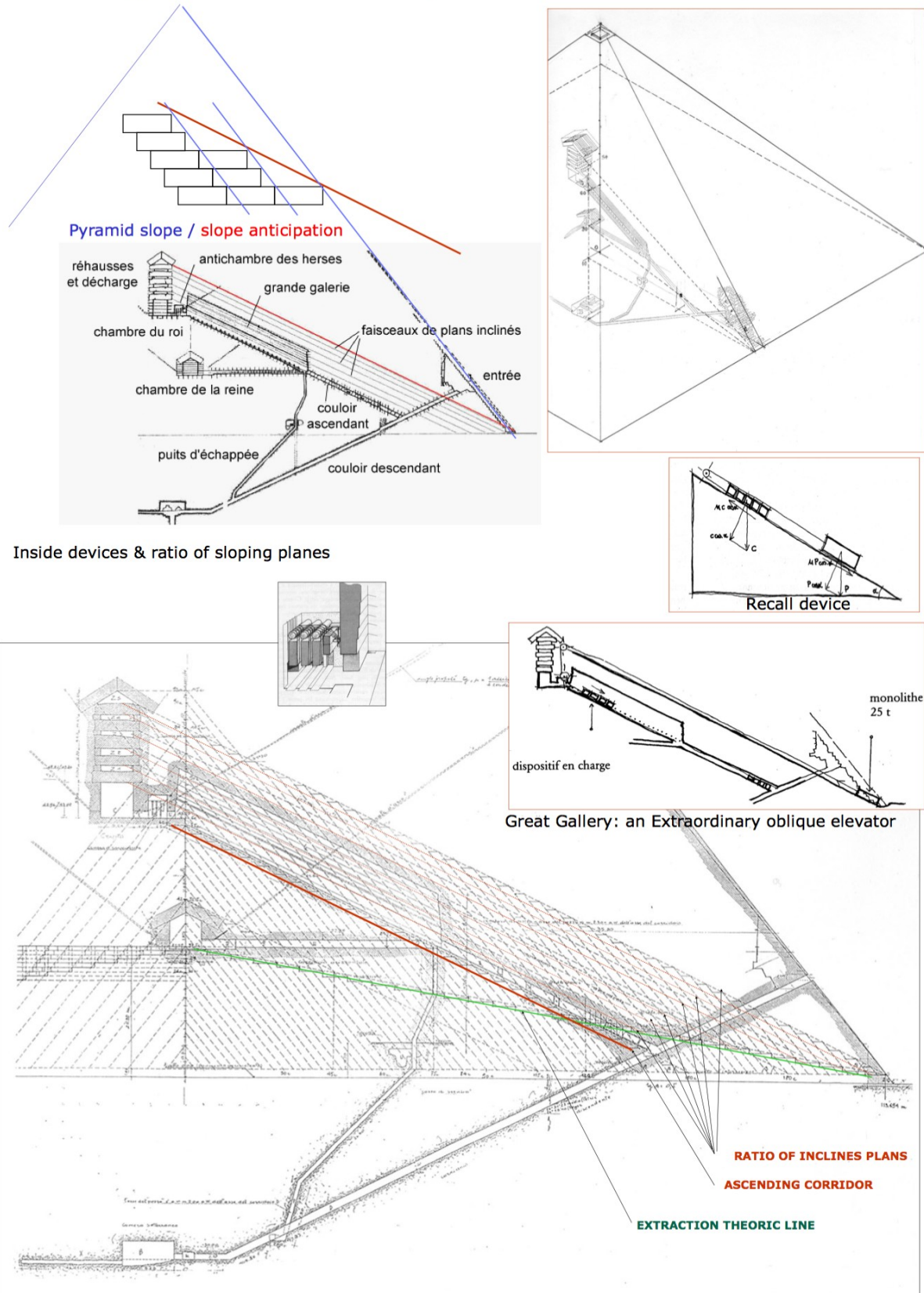
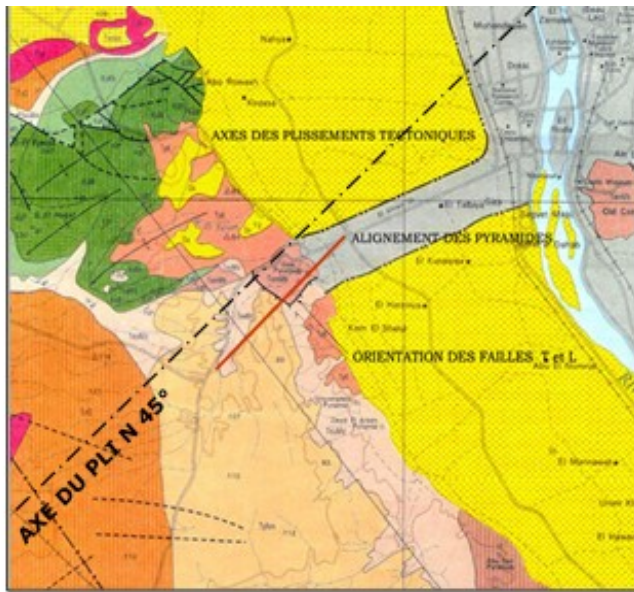
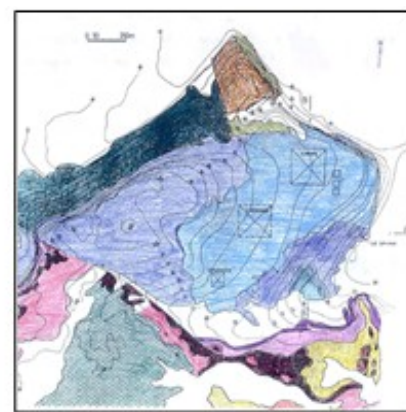


Fig. 7: Geology: genesis and structure of the Giza Plateau

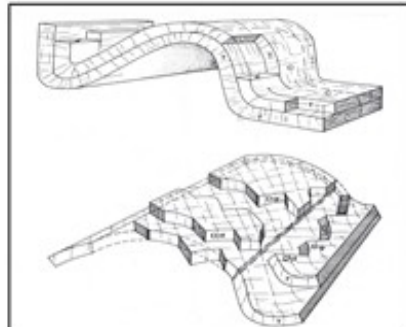
GEOLOGY: TECTONIC & STRATIGRAPHY



CARD FACES	
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Lutetian Eocene Deposits in blue

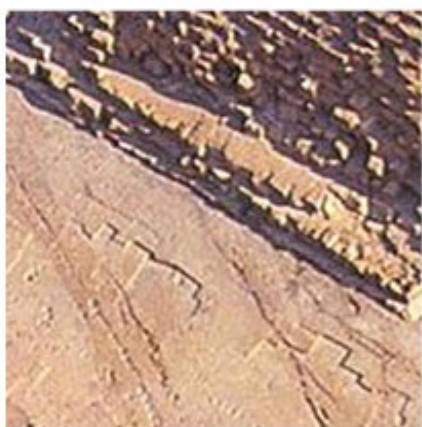


Natural fracturing system of rocks of an anticlinal fold (M. RUHLAND (1972))

1. Faults or large diaclasses : ΔL and ΔT , longitudinal (parallel) and transverse (perpendicular) at the axis of the fold (wide network)
2. Small diagonal diaclasses Δdr and Δdl , due to shear (metric network) determining the unit blocks of quarry.



At the foot of Cheops, north face:



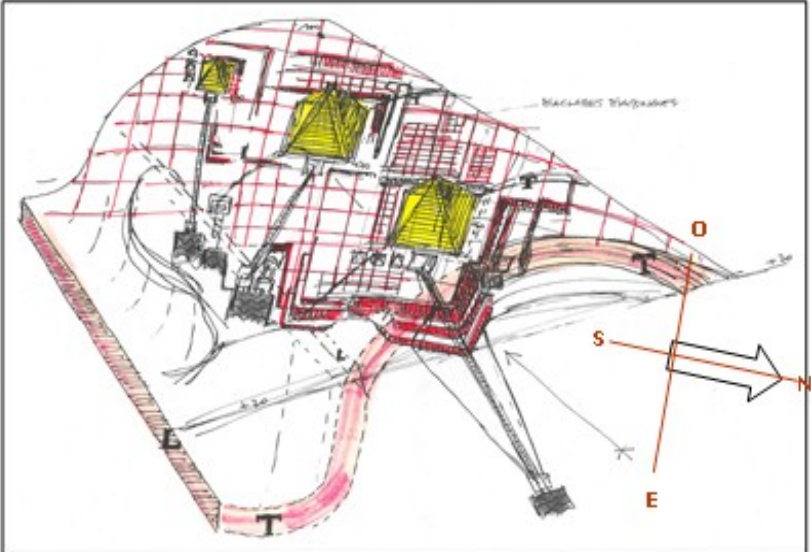
some "removal" fingerprints



Fracking regime proportional to strata thickness



High profile of the main diaclasses



Implementation and orientation scheme of the 3 pyramids of Giza / fracking

- les pyramids are aligned at the top, parallel to the axis of the anticlinal fold
- The quarry orientation is dictated by the diagonal fracturing network
- the 3 pyramids are oriented according to the "surrounding" quarries: N/S and E/W

Fig. 8: Tectoglyphs visible on the bedrock at the NW corner of the Chephren pyramid

TECTOGLYPHS SPOTTED ON THE BEDROCK BASE OF CHEPHREN'S PYRAMID (NW ANGLE)

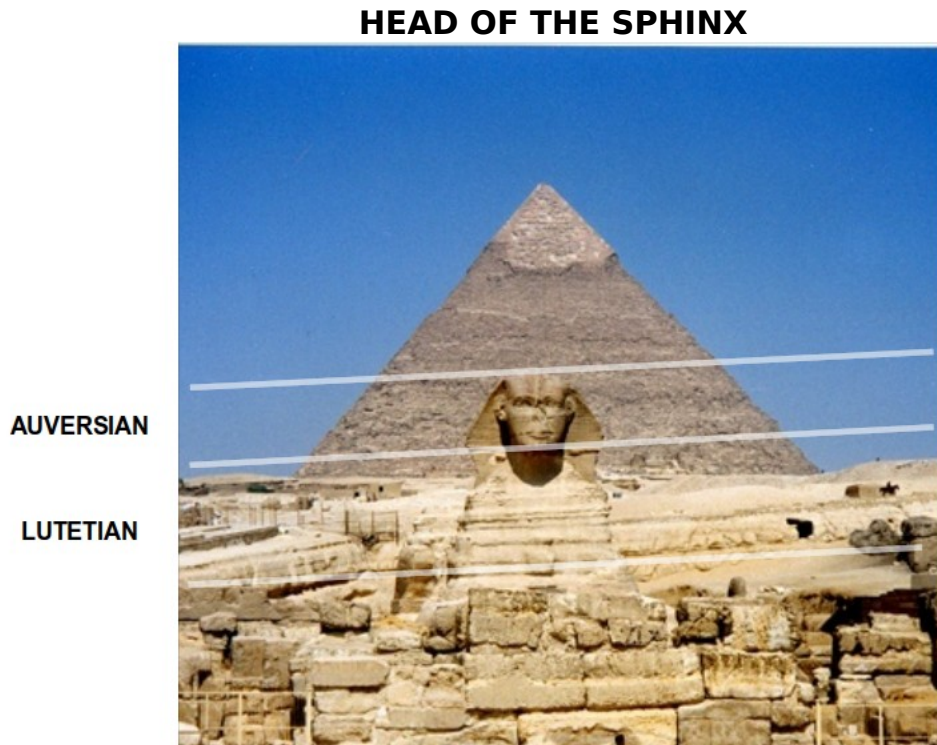


Raymond PERRIER, geologist provides scientific proof of the tectonic movement and secondary array of diaclases «diagonals» of natural fracturing of the Giza Plateau.



Various tectonic marks, here «streaks» engraved on the calcite coating visible on the sliding plane, due to the friction between the 2 sides of a joint of the secondary "diagonal" network (N/S & E/O) with respect to the fold axis (oriented N 45°). (R. Perrier and P. Crozat - 2005).

Fig. 9: The Sphinx's head belongs to the (a) Auversian (darker) layer of the Giza Plateau

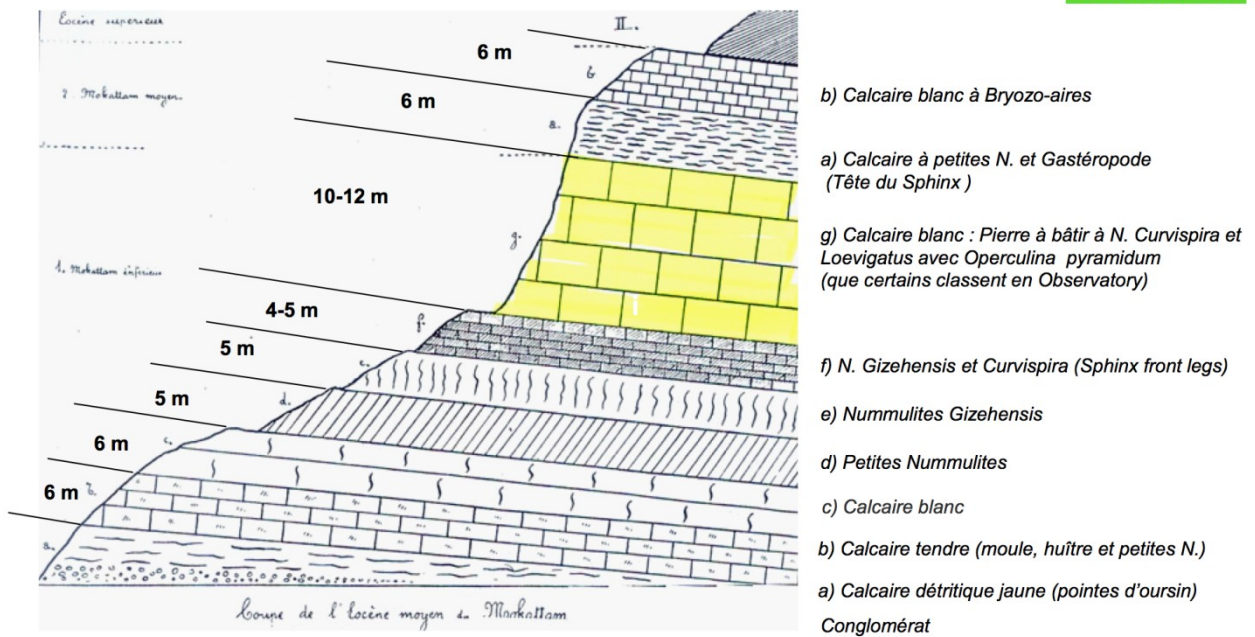


The head of the Sphinx, the upper part of the Tomb of KhentKawes, the High Temple of Chephren, as well as the quarry and therefore the blocks of the pyramid of Mykerinos, belong to the layer (a) (6m) of the Auversian- (darker) according to J. CUVILLIER's Stratigraphy (1930).

Fig. 10: Stratigraphy of the Giza Plateau, established by J. CUVILLIER in 1930

GIZEH PLATEAU STRATIGRAPHY

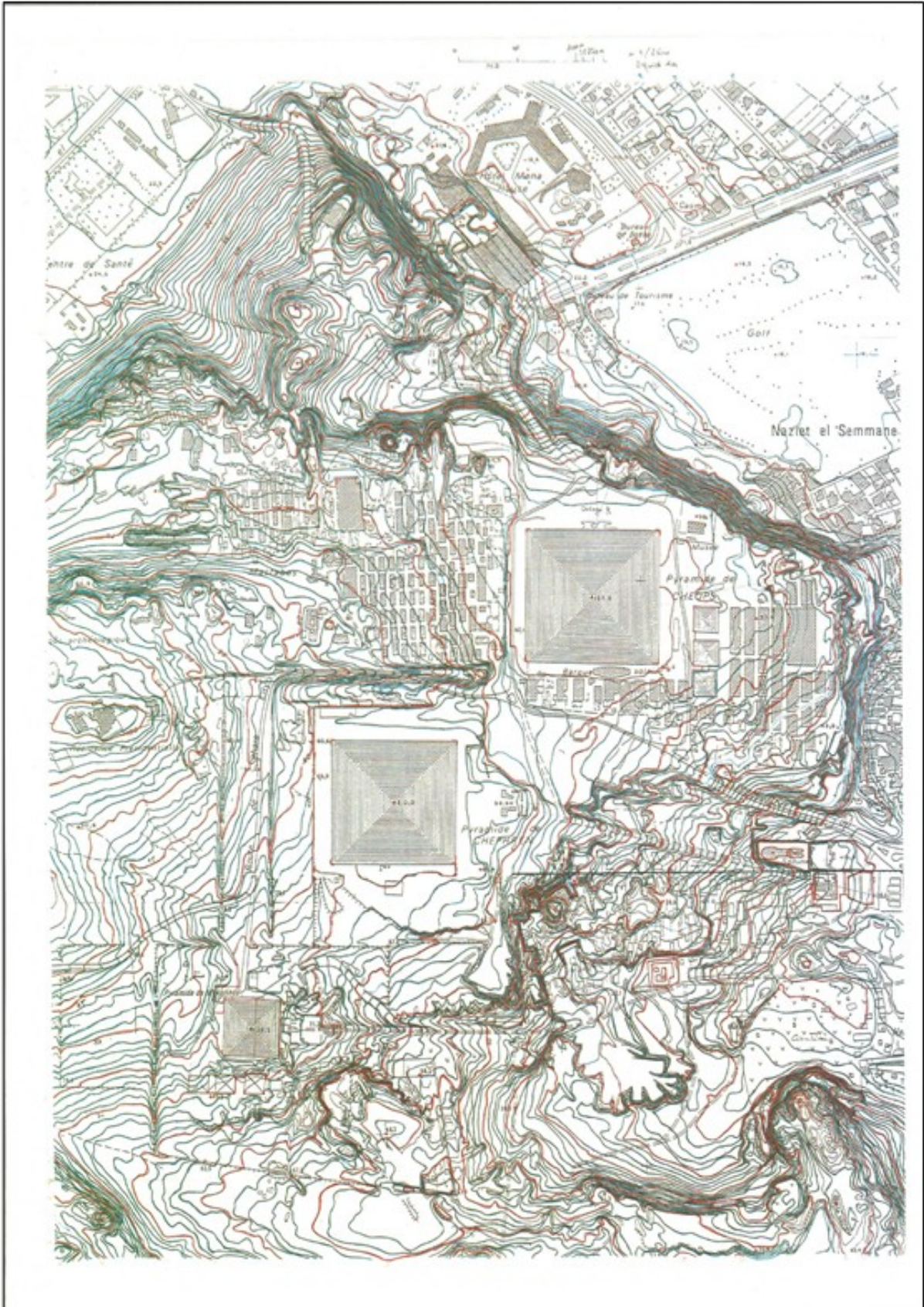
EOCENE MOYEN



Stratigraphic cut of the Giza plateau according to J. Cuvillier, 1930

Fig. 11: Orthophotoplan of the Giza Plateau, realized by the French Institute of National Geography

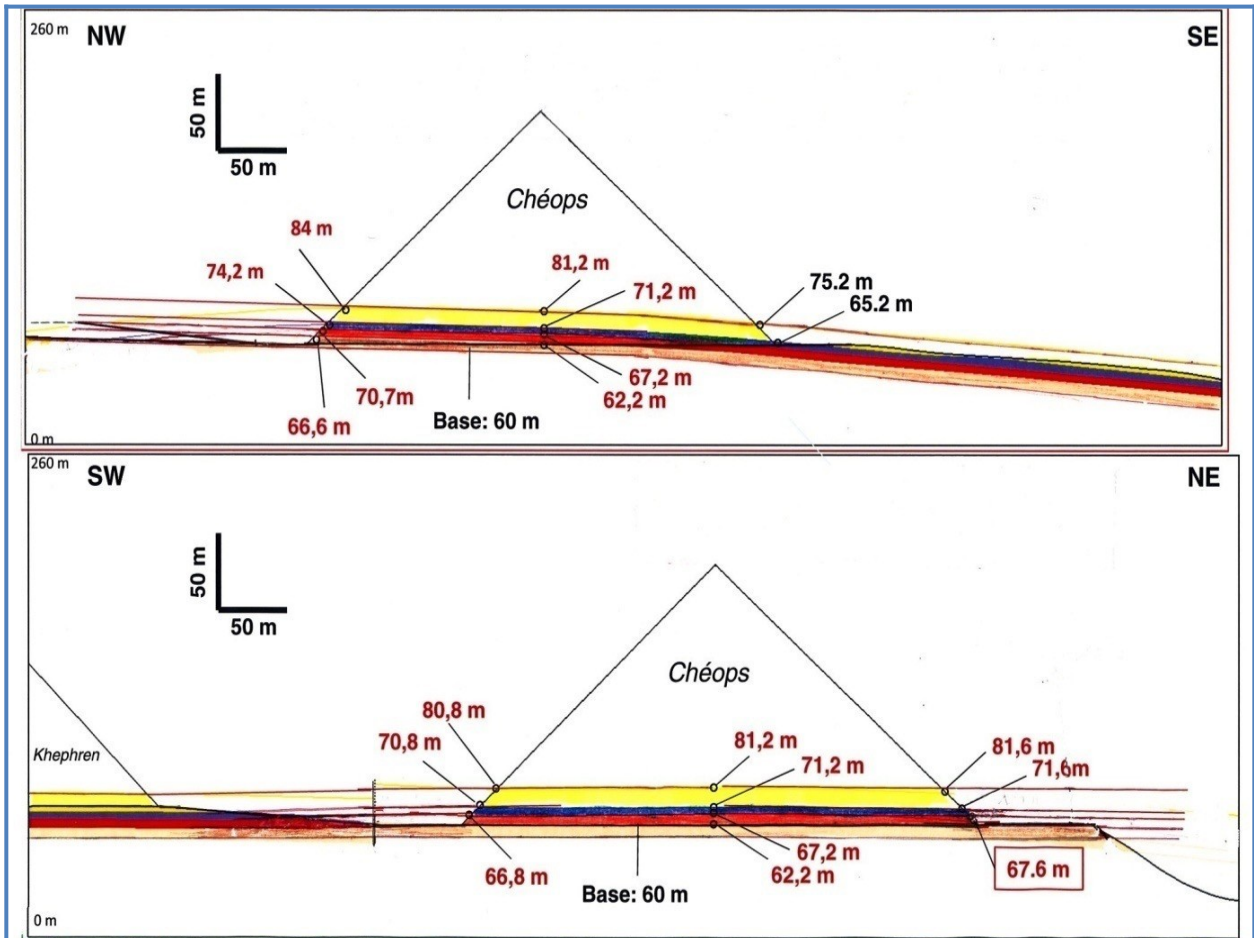
In red: level curves every 5m



Established by photogrammetry and graphic restitution (National Geographic Institute - IGN (France)).

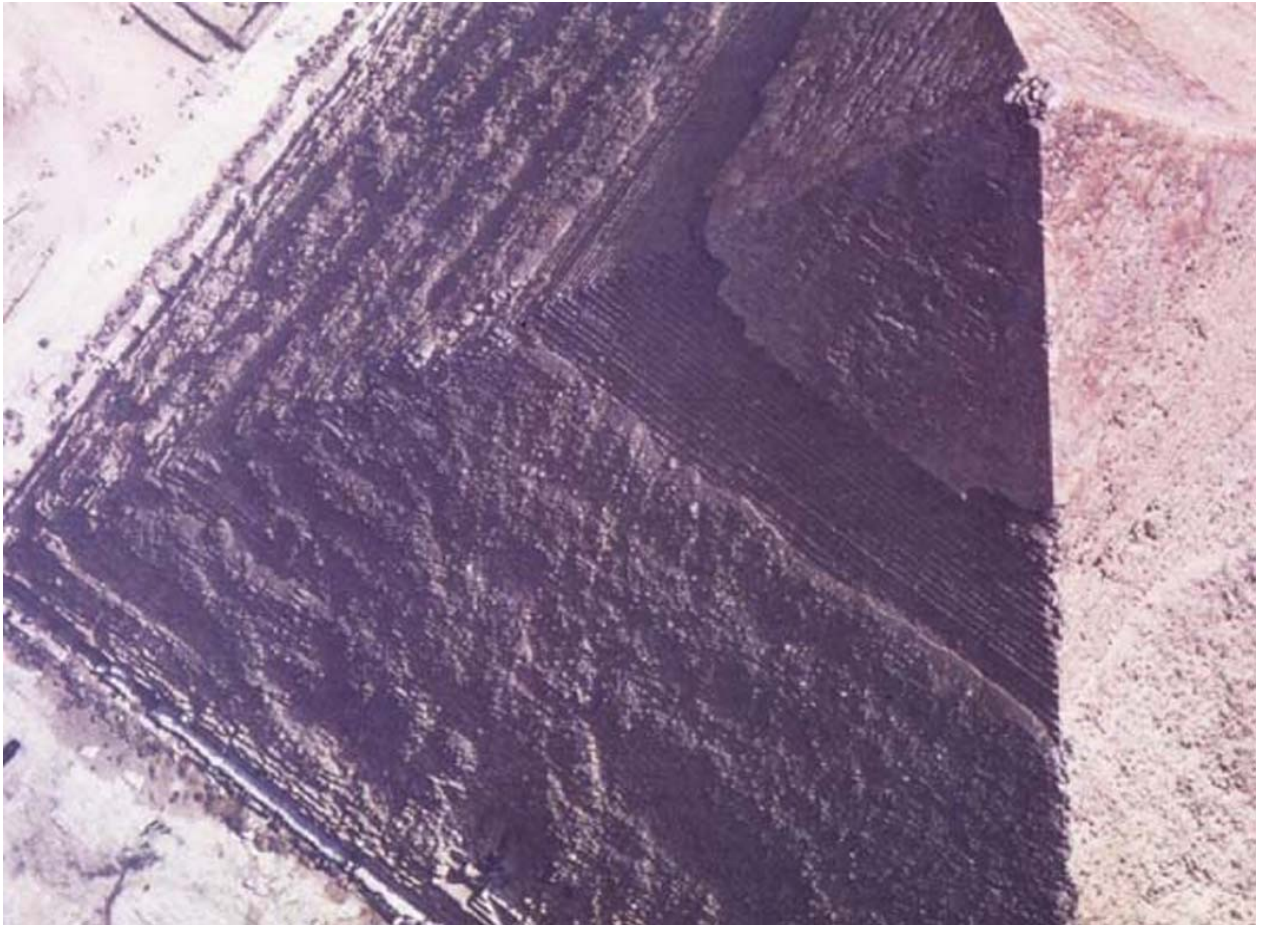
Fig. 12: 3D Simulation of the paleo-topo-stratigraphy of the Giza Plateau - diagonal sections of the pyramid of Cheops: the Queen's chamber is placed on the original plateau

STRATIGRAPHIC CUTS according to the CHEOPS PYRAMID (by diagonals)



The Queen's Chamber is on the layer (g) of Building Stone (yellow), at 21.2m above the base (60m)

Fig. 13: Chephren's Pyramid: several cone envelopes of the pyramidal growth are visible due to erosion



General and detailed view



View of the thickness of the last eroded cone-envelope

Fig. 14: Diagram of the positioning of the large and small voids discovered in the Kheops's pyramid by Japanese Muograpbes in 2017

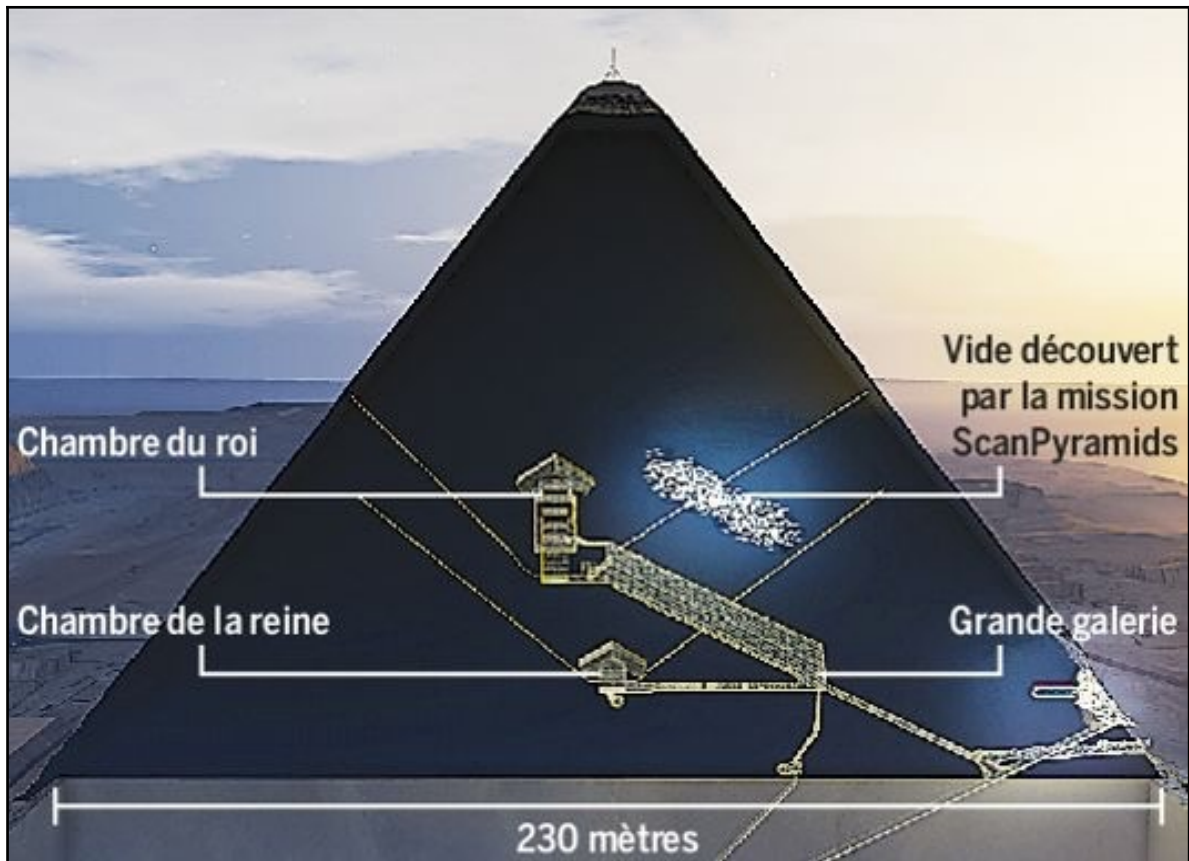
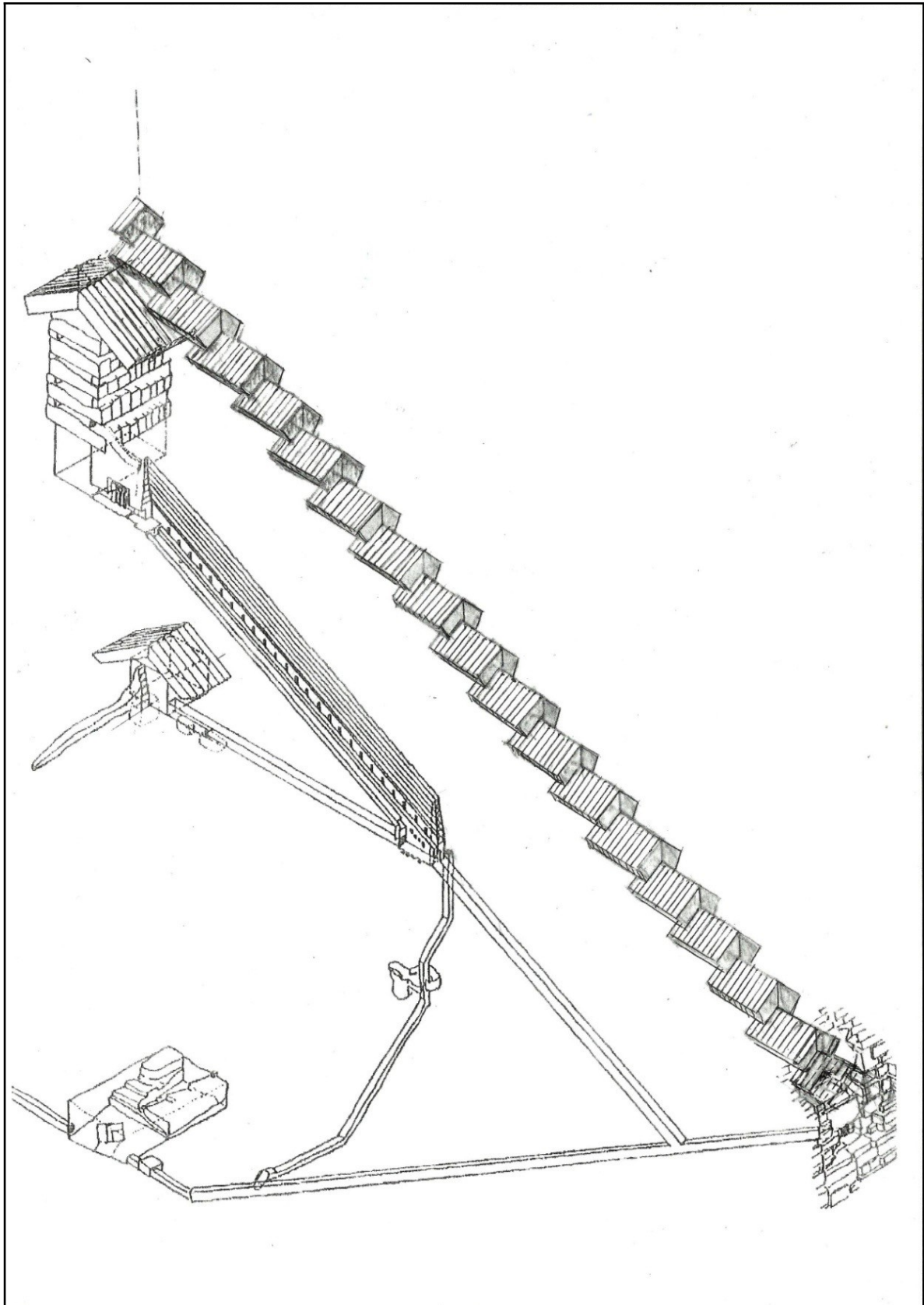


Illustration of the (fortuitous) discovery of the Great and Little Unknown Voids, by the Muograpbes of the HIP / Scan Pyramids team, in the pyramid of Cheops, from the scientific journal NATURE (02/11/2017).

Fig. 15: Axonometric of the "Careful" Chimney of Discharge, proposal of interpretation of P. CROZAT - Open Letter 10/11/2017

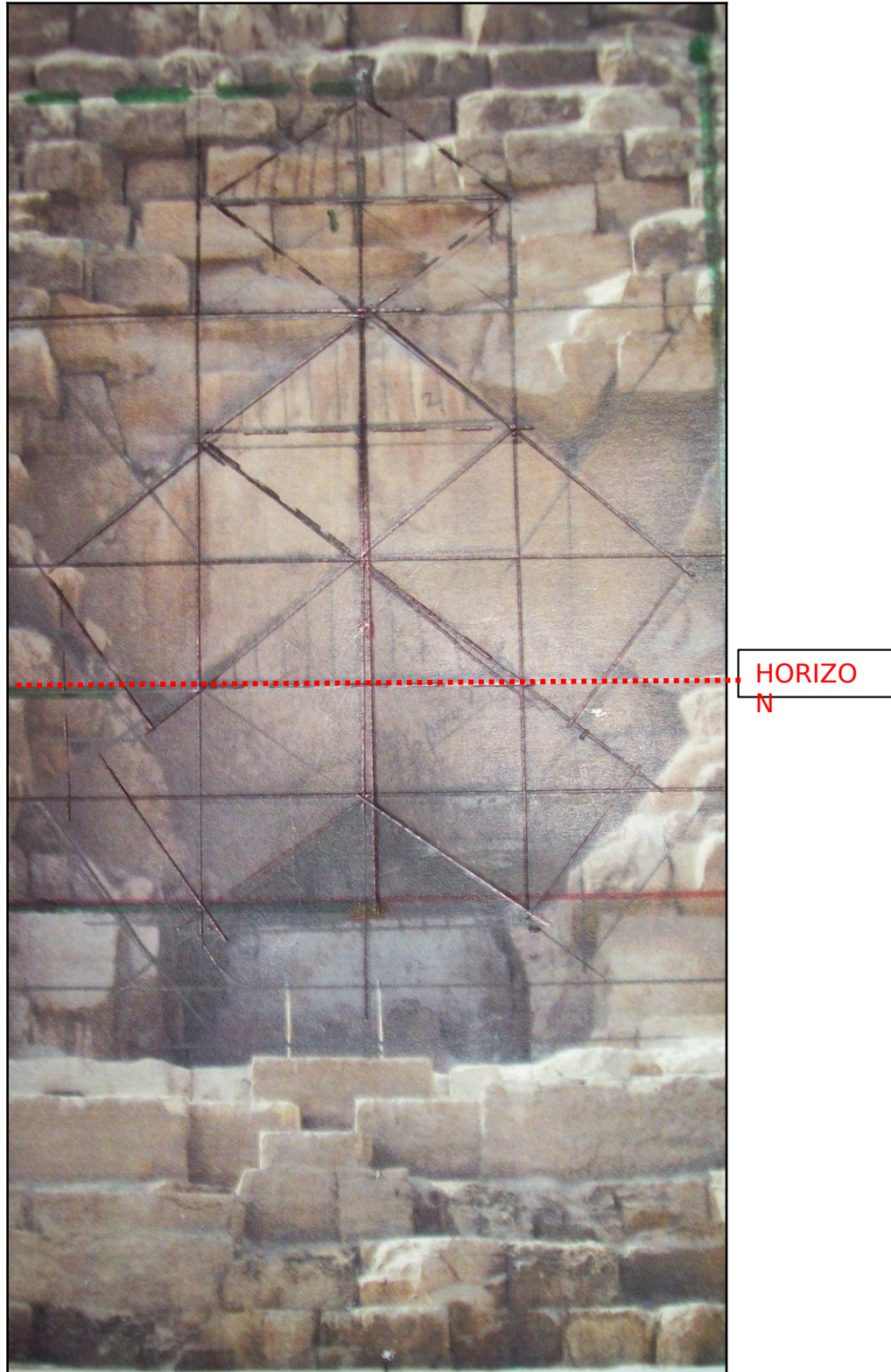
Chimney made of a horizontal alignment of rafters whose static role is to return the loads (of the future part of pyramid remaining to be built) on either side, in the massif under construction.



These discharge chimney leads to the 2 rafters above the Pyramid Entrance (and explains its static role and composition)

Fig. 16: The 2 superimposed rafters on the entry of the pyramid of Cheops are the outcome of the Chimney of discharge

They cannot be explained by the small width of the entrance; they are only the result of this precautionary chimney of discharge (static device) which will protect the Great Gallery (very fragile) and the Ascendant Corridor, against the future weight to come, by the continuation of construction.

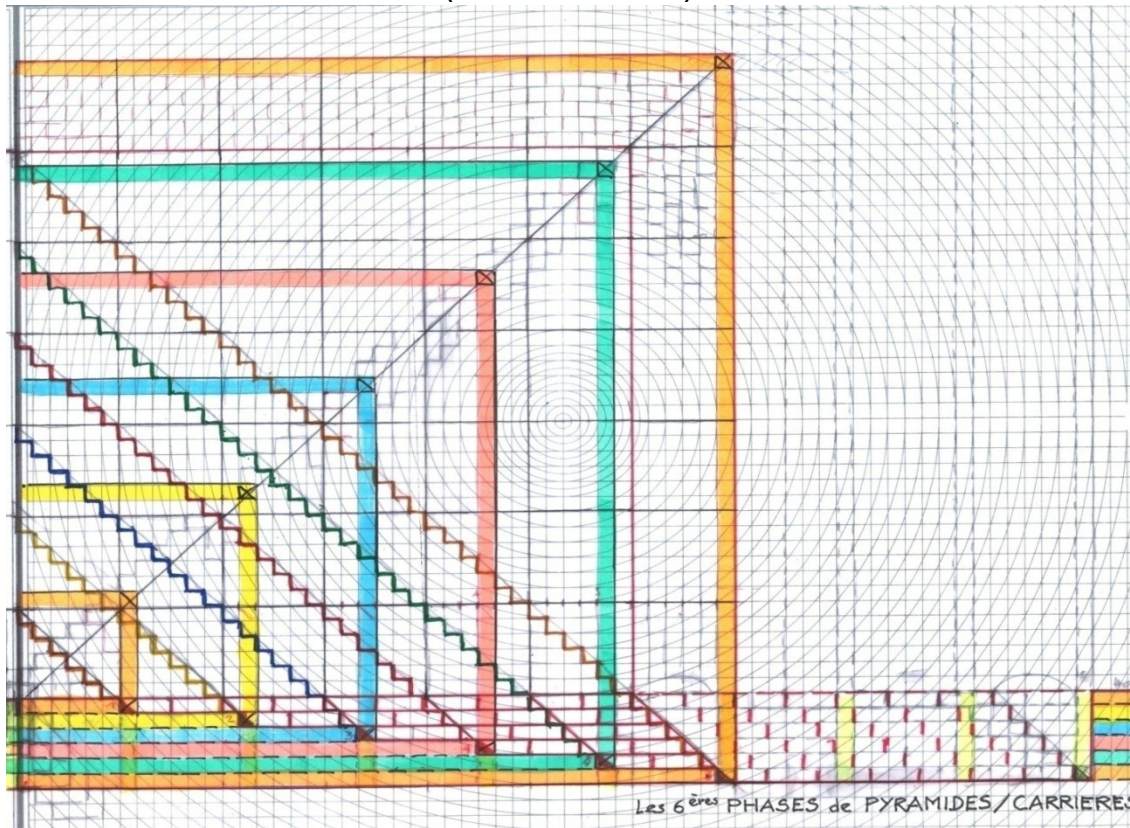


The presence, layout and proportions of these 2 superposed rafters indicate how it was combined in the slope, the stacking up of their alignment, in the Chimney of Discharge.

Fig. 17: Algorithmic Logic on a plane: Modular coordination of the first 6 phases

PYRAMID/QUARRY MODULAR COORDINATION RESEARCH:

An identical module between the Pyramid Cones-Envelops and the Quarry Massifs (of 6 x 6 cubits)



Modular coordination for the first 6 cones-envelops that must be extended to 30 (or 33) phases depending on the cubit considered:

- **0.55 m for 210 seats of 0.70 m or H =147 m by /P. CROZAT;** or
- 0.525 m for 220 heights or H =147 m /J-Ph. LAUER) .

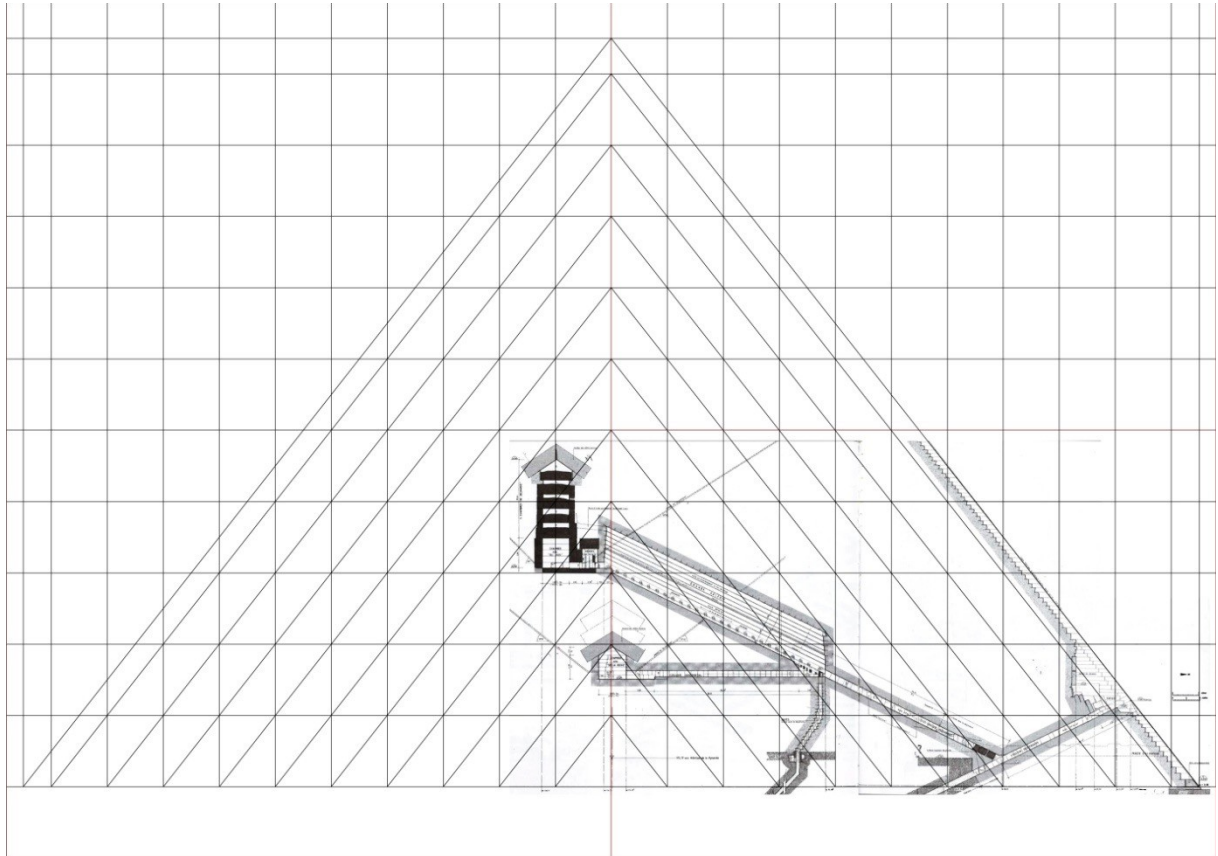
The verification of this hypothesis must be able to be done on any face of the Cones-Envelops (quite simple to calculate with the triangular numbers formula **[N = n (n + 1)/ 2]**) and find the corresponding quarry phase, thanks to the number of massifs (full and simple) available for the phase under consideration.

The example of the 6th phase is conclusive:

- The 6th cone-envelope of Pyramid count (666 + 780) = **1446 blocks**
- The quarry (17 + 19 = 36 massifs of 6 blocks on 6 heights - 36 m x36 b - **1296 blocks**
 - to be added (13 + 15 = 28 massive slumps of a single height or 28 m x 6 b=**168 blocks.**

Fig. 18: Regulatory plot of the Cheops pyramid confronted with the in situ surveys of Maragioglio& Rinaldi Architect and G. Dormion

The confrontation with the surveys of the pyramid of Cheops established by Maragioglio and Rinaldi Architects - MRA (1965) and the more precise surveys of G. Dormion (1996) at the 1/100th and 1/50th, is particularly positive; and the addition of geological layers is also very relevant and revealing



Regulatory tracing established on the ratio $H/1/2$ Base (147/115.5m according to J-Ph. Lauer).

In fact, this report about height has no impact on the constructive system of the pyramids (P. Crozat - 1996) which is governed only by the plan of cutting blocks in the quarry.

Fig. 19: Close-up view of the pyramid of Chephren "which transpires Algorism"



Detail view of the apparatus of the blocks quite visible at the corner, called "support masonry" by Z. Hawass but whose regularity is the very picture of « algorism » (P. Crozat) and the eroded upper cones-envelopes in the lower part of the image



... similarly, the final coating in fine limestone from Tura Quarries(located on the Right Bank of the Nile):

the coloring suggests an algorithmic alternation.

Fig. 20: Manual mining quarries in the 21st century in Egypt.



Manual extraction quarry still in existence today in the Observatory Layer at HELWAN



The Quarry's extraction method and gestures have hardly changed in the past 4700 years.

Fig. 21: Commentary on the photograph of the summit of the Chephren's Pyramid published by Dr. Z. HAWASS in his Album "Treasures of Pyramids" (p.59)

« Top of Chephren's pyramid in fine limestone of Tura: The **supporting masonry here appears regular**, under the coating, **but the depth of the blocks and degrees varies considerably (!)**. The debris of the support masonry adheres further to the core, after the removal of the coating »



(!) : By contrast, we propose that the "debris" is due to the erosion of the cone-envelops, letting one see the algorithmic organization of the construction that goes on by successive layers all the way to the core of the pyramid. It is the very system of pyramidal accretion, QED. (P. Crozat- 2002, and 2019).

Fig. 22: Coordinating diagram (plan and section) of the Quarry-Pyramid relationship

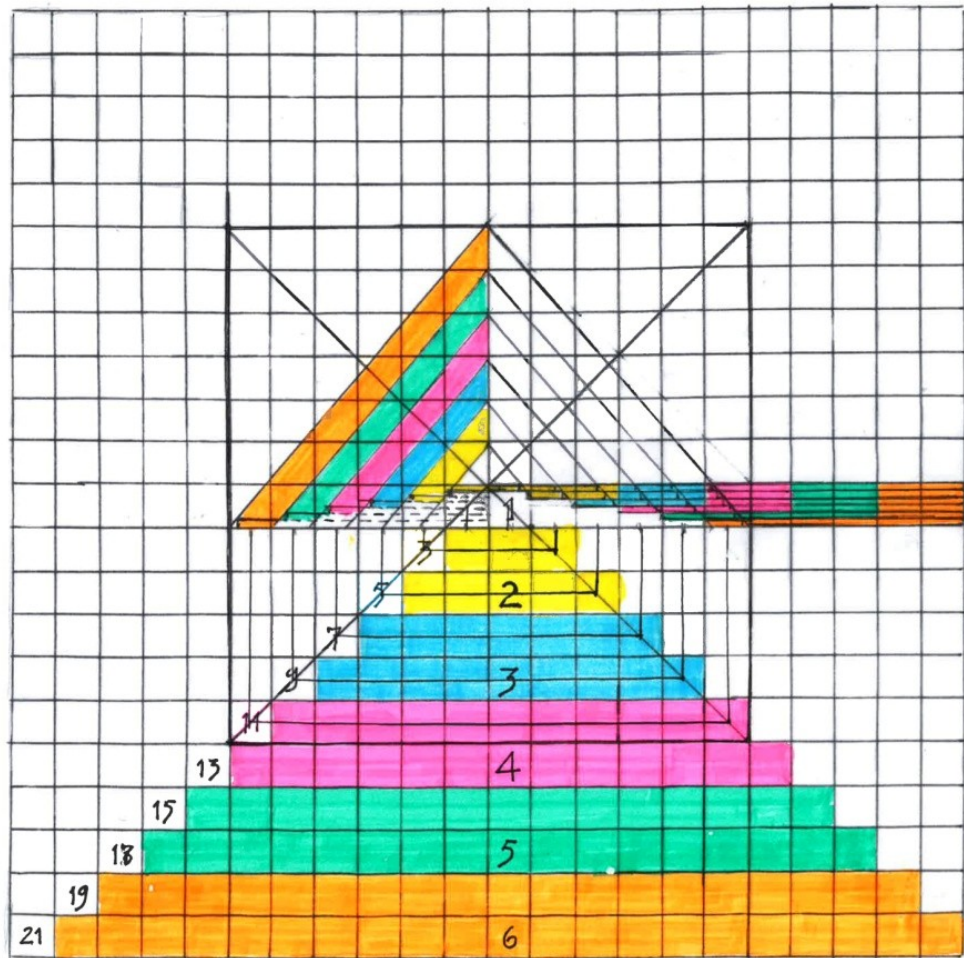


SCHÉMA RÉGULATEUR des 6 ères PHASES (Plan - Coupe)

IN PLANE:

This regulatory scheme for coordinating the PYRamide-on-Quarry relationship over the first 6 phases of pyramidal growth (which will include 30) indicates:

- the surface of the PYR. (6 phases): 12x12 central square
- the Quarry Surface. (6 phases): 22x22 SQUARE
- the central pyramid being empty (or full).
- Successive phases of QARRY (different colors in phases) with their color matches.

IN CUT:

- at left, with the corresponding envelope cone phases of the PYRAMID.
- at right, with the corresponding phases of QARRY.

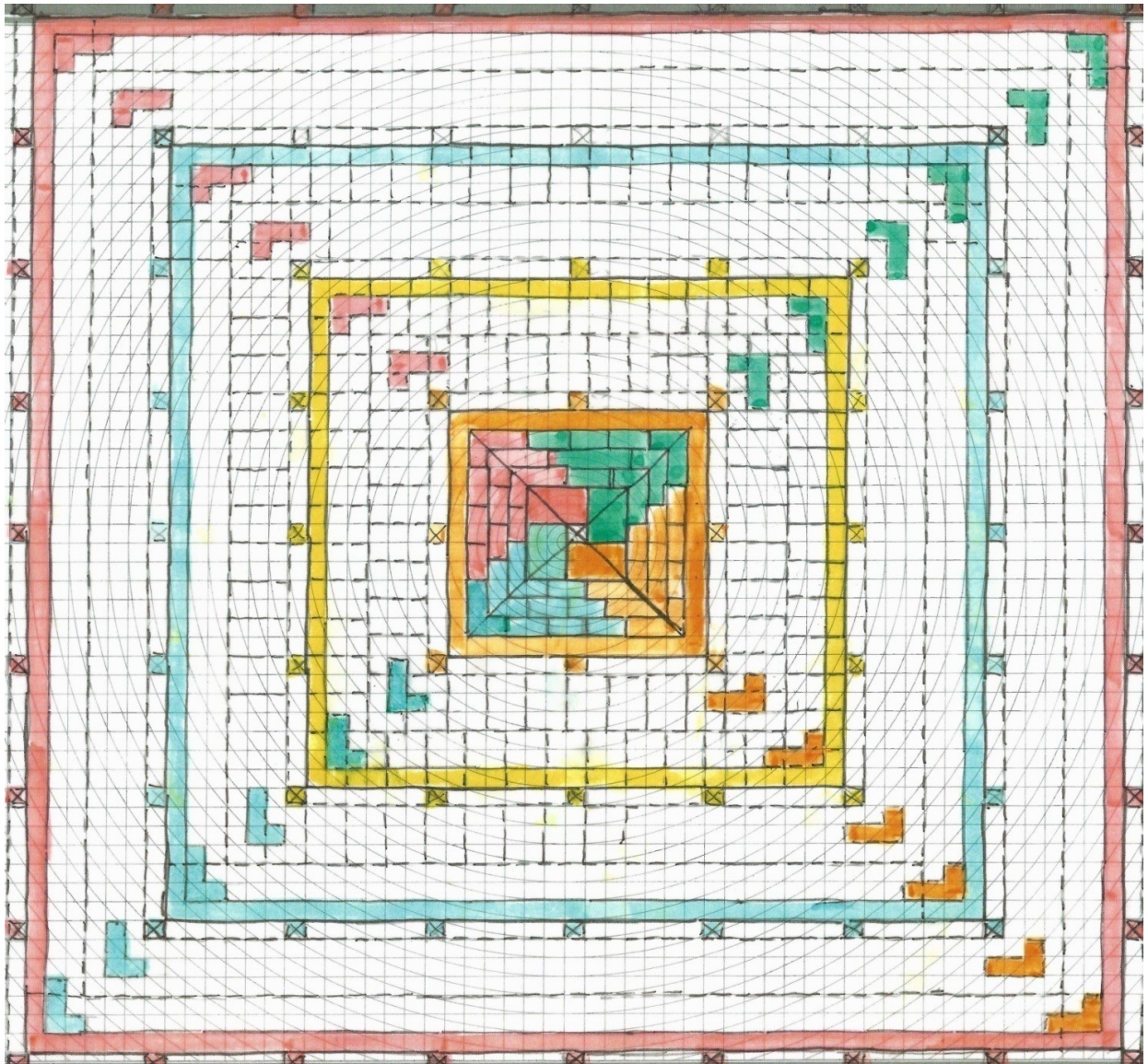
This diagram will apply to the 30 phases of pyramidal, homothetic growth, not "geometric" (geometry will exist only with the Greeks) but by continuation of this "algorithmic logistics" (here installed), by successive additions of 25 others Phases.

This pre-Pythagorean algorithmic logistics, closely linked to the 5 Great Smooth Pyramids, constitutes a technological - conceptual leap that only Egyptian builders have been able to overcome.

This final "cyclopean" phase of the evolution of methods adapted to the building materials provided by the site of implantation: the very analysis of this evolution made in this research tumbles and annihilates all desire for a "ramp" solution.

Fig. 23: Modular coordination: successive phases of borrowing at the periphery itself in the Quarry

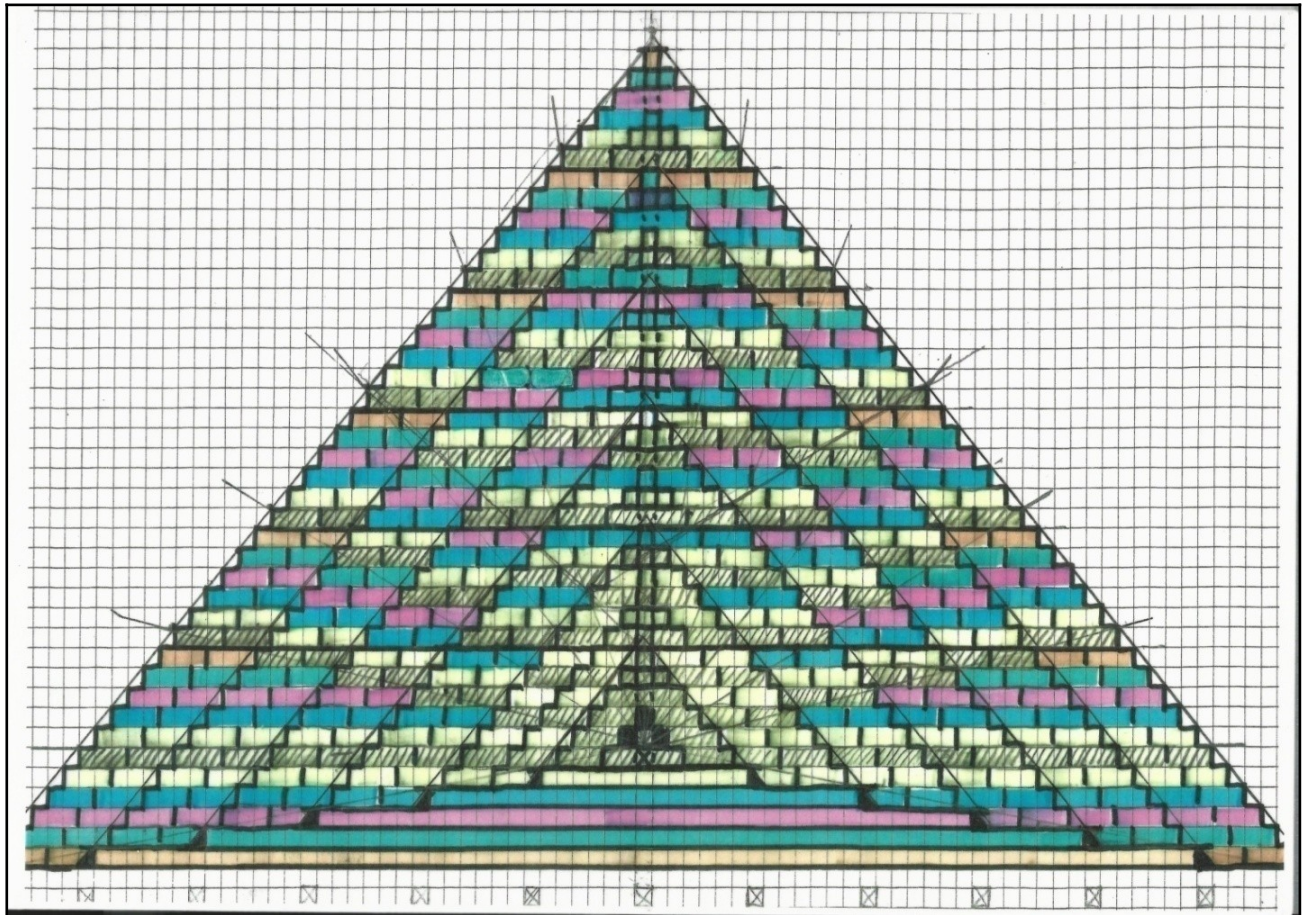
From a first small starting pyramid (center) - providing the necessary blocks for the construction of the successive cones-envelops of the "pyramidal increase".



Plane view of the division of blocks into successive quarries corresponding to the different phases of pyramidal growth.

Fig. 24: Modular coordination: successive phases of the pyramidal Pyramid increase

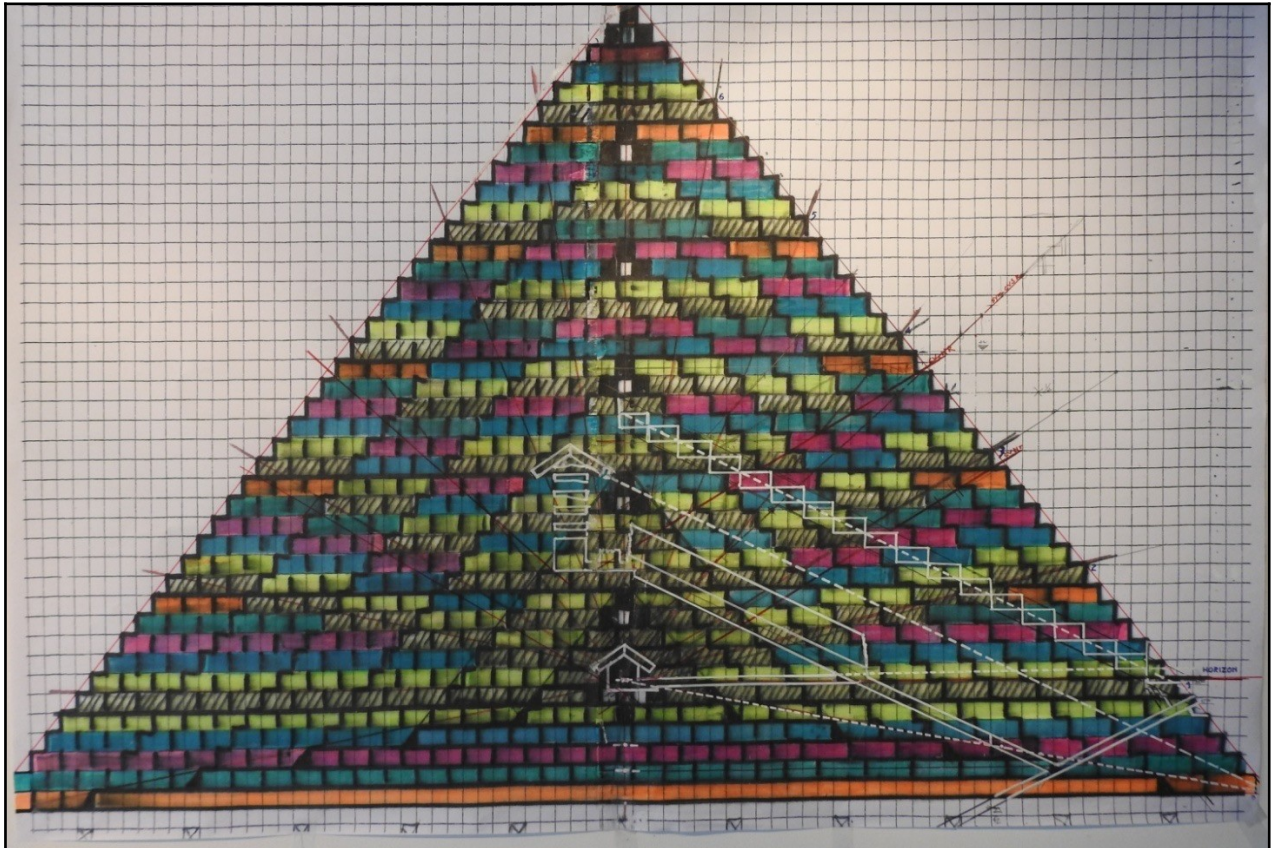
**At each pyramidal growth phase:
the height of the Quarry is 1/7th of the height of the Pyramid.**



The composition of the cone-envelope increases with each phase: 1st phase: 1 color; 2nd phase: 2 colors; 3rd phase: 3 colors; ...; 30 phases: 30 colors.

Fig. 25: Superimposition of the interior devices of the pyramid of Cheops (after G. Dormion) on the (colored) drawing of the "Algorithmic Logistics", highlighting their conjunction

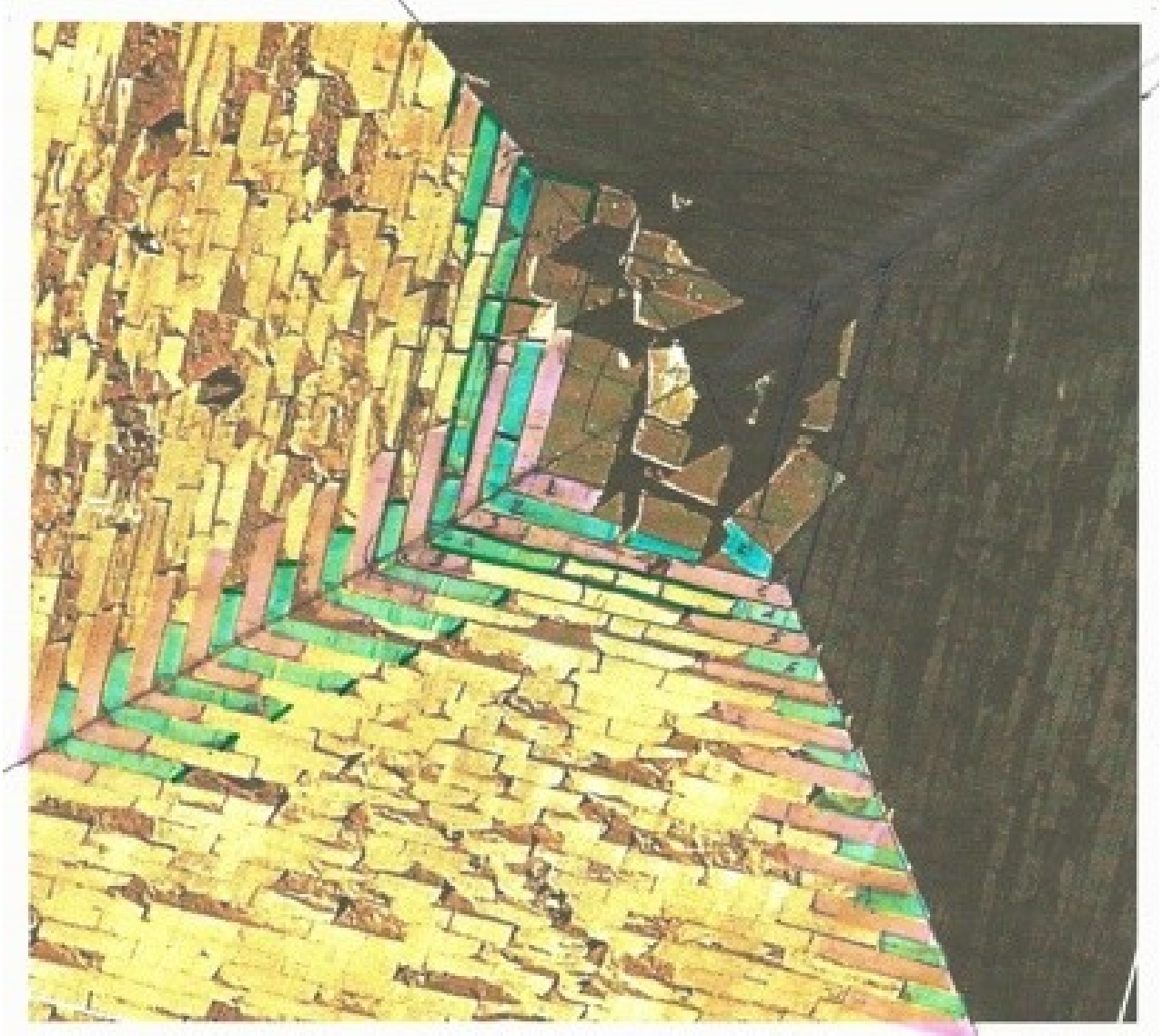
Corridors, King's and Queen's Chambers, Great Gallery and the Discharge Chimney (P. Crozat, Proposal - 2017) and including the ventilation ducts (here in red).(based on survey by G. Dormion, see white lines, 1996 - Modified 2004) .



Work rough at scale 1/200th established on 08-04-2019:

- 7) The center of the pyramid is located on the floor of the Queen's Chamber at a height of 21m compared to the external ground (000). It is also the center of the quarry the height of which equals 1/7th of the height of the pyramid.
- 8) It is thus the homothetic center of the pyramidal volume increase. The center of the radiant is always 1/7th of the observed enveloping cone. (7 times 21m - 147m or 210 benches of 0.70m on average on the network of the quarry. We propose that the algorithm used is the royal cubit of Cheops measuring 0.55m. We think that Cheops pyramid has never had 220 benches (J-Ph. Lauer) but only 210 and the 21m of its quarry correspond to 30 benches with an average value of 0.70m (or 40 common Cubits), even if these benches are of varying heights.
- 9) **It is not a question of "sacred geometry" often referred to but of algorithmic logistics whose existence - at the time of the Great Pyramids of Egypt - was authenticated by Michel Serres, in his book "The origins of geometry" . However, not being a construction practitioner (specifically attached to concrete actions), he did not perceive the direct or even ontological shift realized with the leap in technology with the cyclopean blocks of the Great Pyramids that also necessitated the invention of the lifting machine, when compared to the technical continuum of earlier tumular works. (P. Crozat-Nov. 2019).**

Fig. 26: the 2 combined algorithms of the Chephren's Pyramid.



M. Bertinetti's photograph (White Star - 2004) published by NG (F) "Egypte entre ciel et terre").

The covering of Chephren's Pyramid in white limestone from the Tura quarries, on the opposite side of the Nile. The study of this photograph, that we have colorized, indicates a second algorithm that allows the crossing of the angle blocks on the edges, thus insuring a better stability and durability over time and voluntary damages.

It overlays and combines with the first algorithm that deals with the construction of the enveloping cones. The first algorithm constitutes the constructive system of the great pyramids, and does not cross the angle blocks.

1st algorithm, for the construction: assembling of headers, i.e. the length of the block is perpendicular to the face.

2d algorithm, for the covering: assembling of stretchers, i.e. the length of the blocks is perpendicular to the face. The stretchers are larger than the headers, which allow the definitive smoothing completion, dixit Herodotus.

Fig. 27: E. Morin "Introduction to complex thought"

Defining the idea of an "open system" versus the "closed system"

"The intelligibility of the system must be found, not only in the system itself but also in its relationship with the environment and that this relationship is not merely an addition, but it is constitutive of the system." A term that opens the door to the "theory of evolution" that he pursues by leading to the notion of interaction in "open system" and "eco-system" and then that of "self-organizing system" ».

(The "self-organizing system" ESF Publisher, 1990, (p. 31))

In fact, once the **Algorithmic Logistics has imposed its rule** -from the first stacking: the length of the blocks is absolutely dictated by the grid of trenches of the QUAR. and the crossing of the blocks is fixed by the "movement" (lever arm travel and support point position). As for the height of the blocks it can vary from one pyramid to another, of course) but also inside the pyramid of Cheops if necessary (within the limits of the lifting machine), because this hazard will be compensated by "**horizontal stalling apparatus**" - the most thrifty is A. CHOISY - and this from one block to another in the same cone-envelop or from one cone-envelop on the other (this nevertheless constitutes an important but yet easy subjection because this stone is tender, especially the layer (g) of building stone (12 m).

Chephren solved this difficulty **by exploiting only the layer (g) building stone (12m)** (compact and tender, easy to cut) without digging into the lower Layer (f) (4-5m) (less auspicious) and normalizing its blocks, which will require it to follow this deposit (g) where it is located that is upstream, above the front of size (cliff) to the west where one can spot quarry remnants.

For his part, **Cheops** after making **a first nucleus of cones-envelops with the Layer (g) building stone (12 m)**, pyramidal nucleus that contains all of its interior devices, governed by Algorithmic Logistics (up to where the corridor ascending "descending" leaves this layer (g), (i.e. 11m in the pyramid) will borrow in the underlying layer (f) (4-5m) but will be forced 4m lower - The Layers (e) (5m) and (d) partial are difficult to extract - to go find where you still find them, i.e. to follow this layer (g) upstream to the West and to open a quarry in the hills (on the future fields of the Mastabas to the west) updating the Couche (f) that can be found in situ, up to the foot of the **Mastaba G 2000 (forming the top of the first cuesta)**, which belongs to this Layer (g) Stone to be built.

The Mastaba G 2000 offers a strong front to the east well recognizable by its **karstic erosion**. It is precisely this Contribution Face West that will have made it possible to decentralize the top of the pyramid to the west of about fifteen elbows.

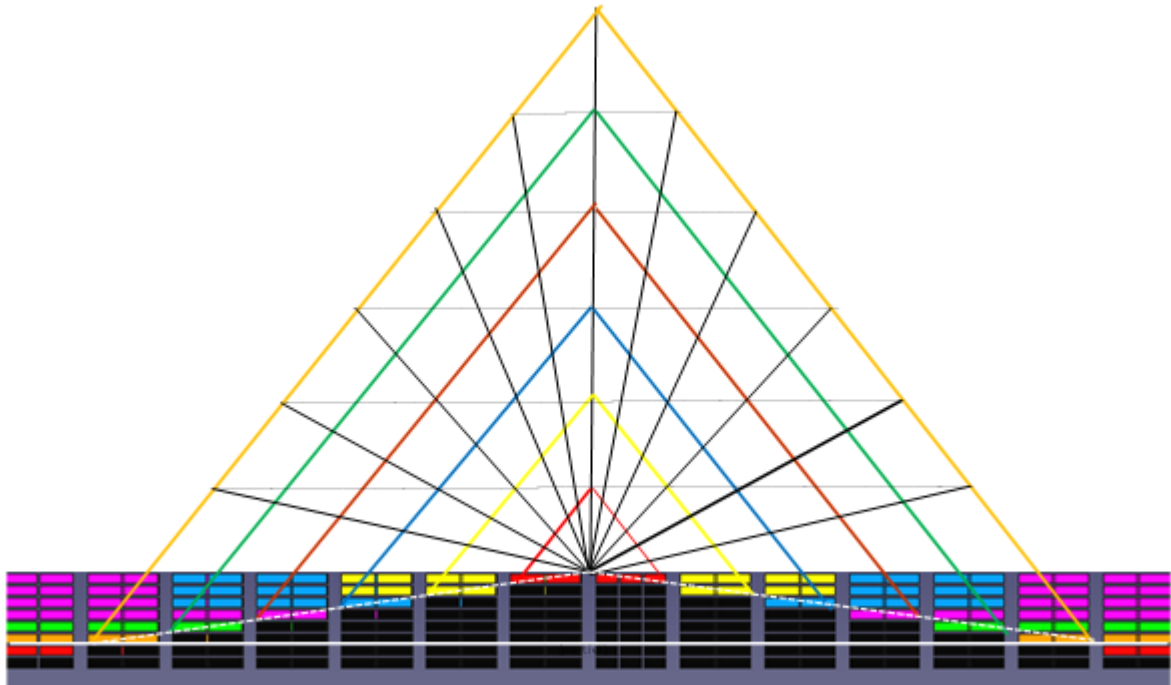
These various observations of the order of Algorithmic Logistics superimposed on stratigraphic and petrographical data make this constructive system "open and its relationship to the environment is constitutive of the system: either "a self-organizing system."

Finally **the final coating in Fine Limestone** (white) extracted from the **Quarries of Tura** (located on the other side of the Nile) will be brought, (by river in times of flood) and laid like the previous cones-envelops (with the same machine), and **then will be swallowed**, i.e. that we will break the steps of the blocks to make it smooth, not to be beautiful **but to be "completed"** says Herodotus: **"the pyramid was completed from the top and lower bleachers to the base of the building": thus no longer having the possibility of support (bomides: ensitment) one can no longer use the "machine" preventing its continued construction.**

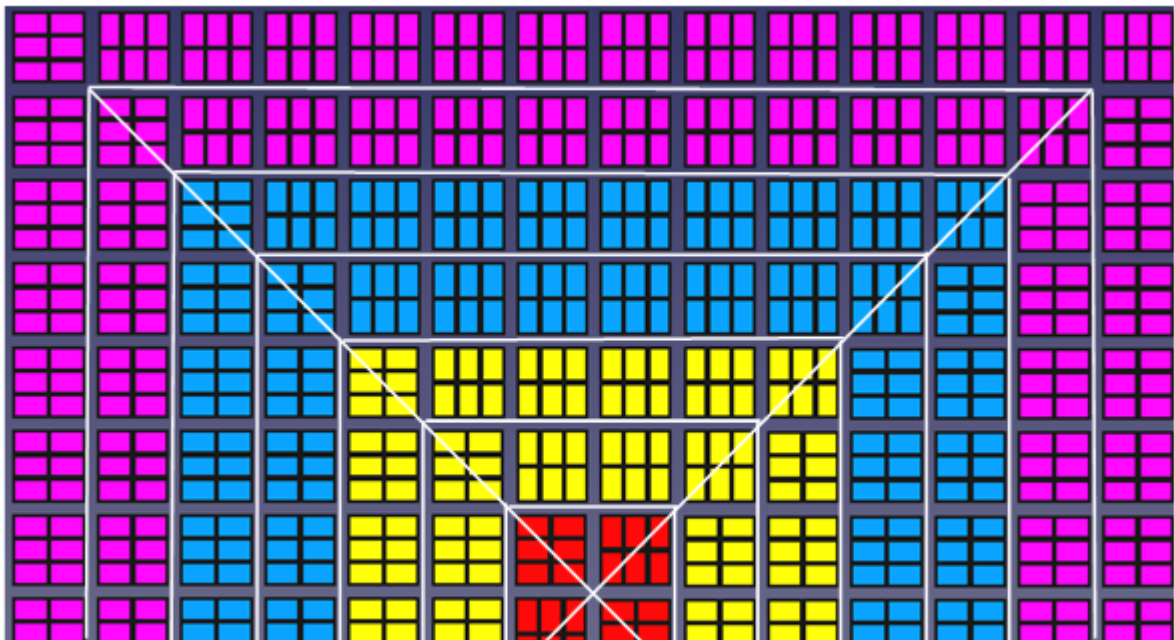
Herodotus' text is technical and precise: it contains the "system" solution.

Fig. 28: The Kinematic modeling of the construction of the "theoretical" Model of Algorithmic Logistics began. (P. Crozat & B. Hostalery -2020)

ANIMATED INFOGRAPHIC MODELING BASE (2019)
The VIth first phases of PYRAMID / QUARRIES (in CUT and PLANE)



Cut view of the first 6 phases of the Pyramid on the corresponding Quarries (partial)



Plane view of the first 6 phases of the Pyramid on the corresponding Quarries (partial)

Fig. 29: An Algorithmic Logistics Example: Digging of a channel under Mao Zedong



Algorithmic logistics induced by the individual shovel: method inherited from the depths of the ages, taken up because of manual work.

Fig. S1: The 3 rooms in Cheops' pyramid by L. Borchardt:

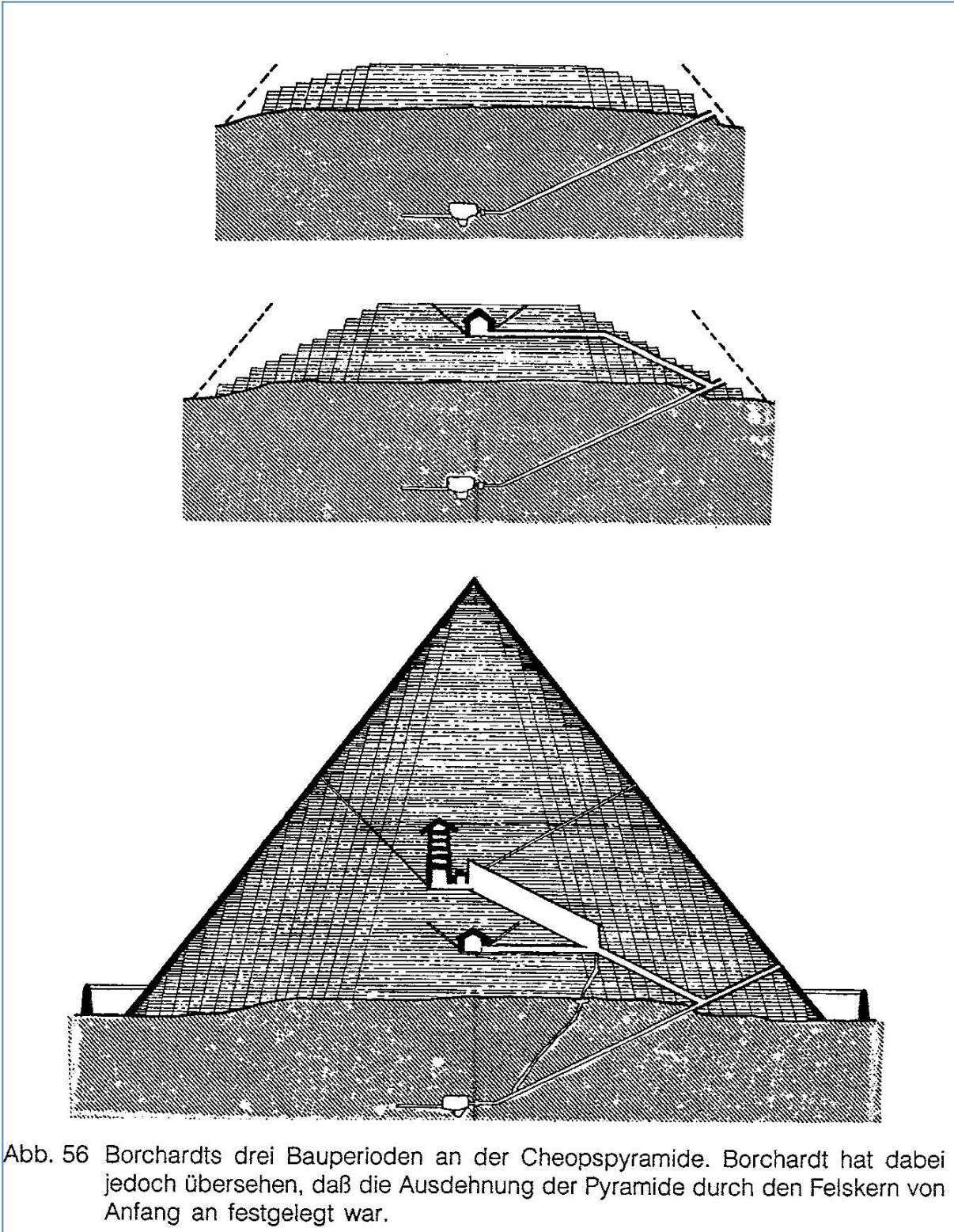


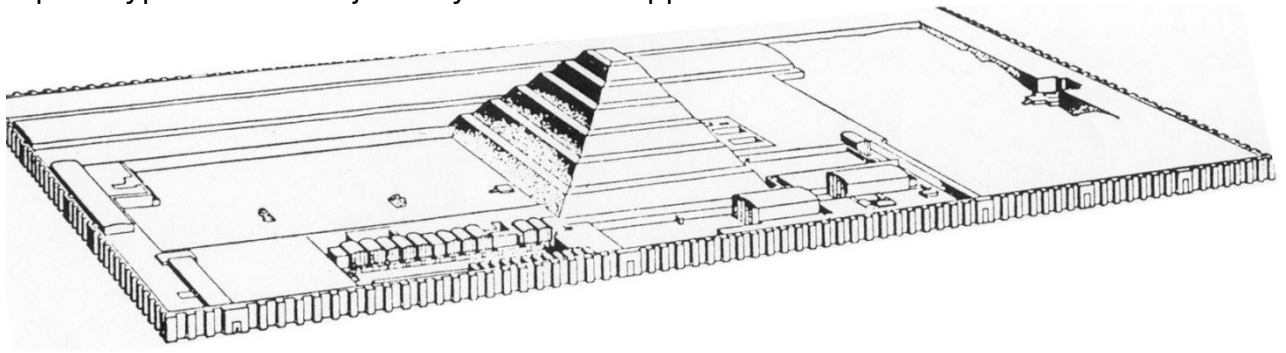
Abb. 56 Borchardts drei Bauperioden an der Cheopspyramide. Borchardt hat dabei jedoch übersehen, daß die Ausdehnung der Pyramide durch den Felskern von Anfang an festgelegt war.

The existence of three successive chambers inside the pyramid of Cheops is usually accepted by classical Egyptology, without further checking. This interpretation depends on an imaginary scenario that is fundamentally put in

question by the constructive logic method of pyramidal accretion, derived from Herodotus' text, and developed further in the text.

Fig. S2: Step Pyramids

They are built with small blocks (superior Eocene period) that can be carried by hand. The prototype would be Djoser Pyramid in Saqqarah.



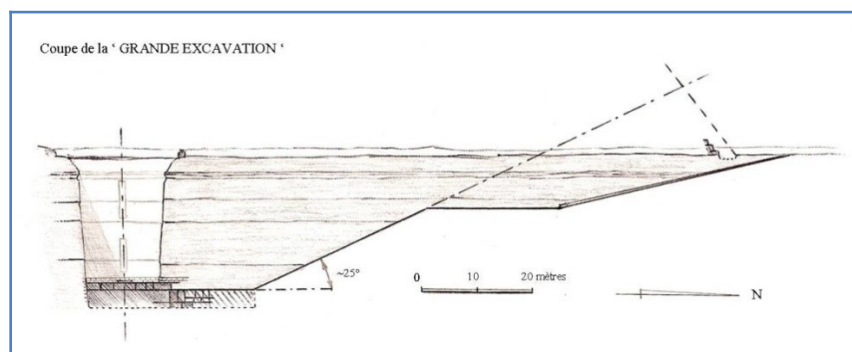
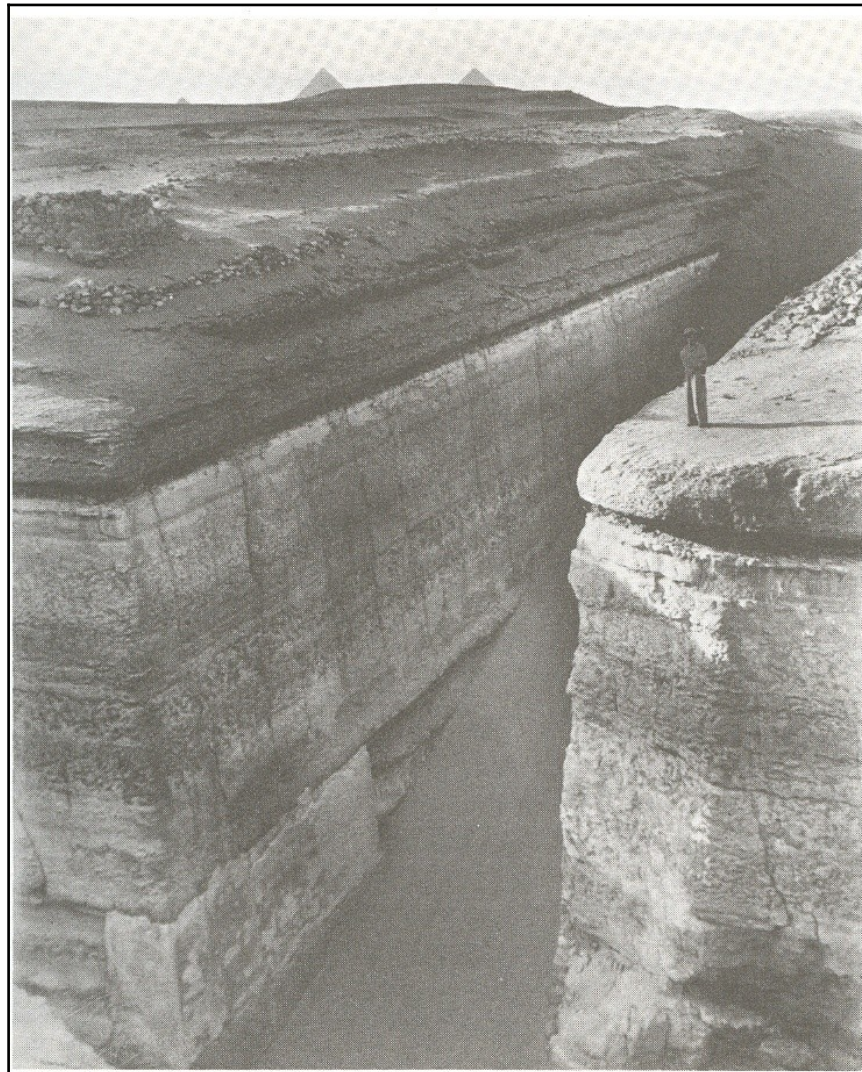
Djoser funerary complex in Saqqarah: the lateral courtyards are where the materials (small blocks) that constitute the step pyramid were taken from. The bottom of the quarry rests on a layer of fused pebbles, itself resting upon a layer of mixed clay and limestone, called "tafla", improper for construction.



Behind the facing walls (made with quality stone from a different location), one recognizes the local deposit (small blocks) taken from the lateral courtyards. This deposit was used to build the pyramid with steps (10 meters) that are not there for style, but that reflect the constructive method itself; the height is the same as with the ramparts of cities, and it is due to the length of the wooden scaffolding masts or trestles.

Fig. S3: Great excavation of Zaouiet el Arian (IIIrd or IVth dynasty)

The ditch dug to place the sarcophagus is identical to a step pyramid's (IIIrd dynasty). This pyramid was never built, since one can see its beds of intact materials, small blocks near the surface (Superior Eocene), on top of the massive under layer (Middle and Inferior Eocene).



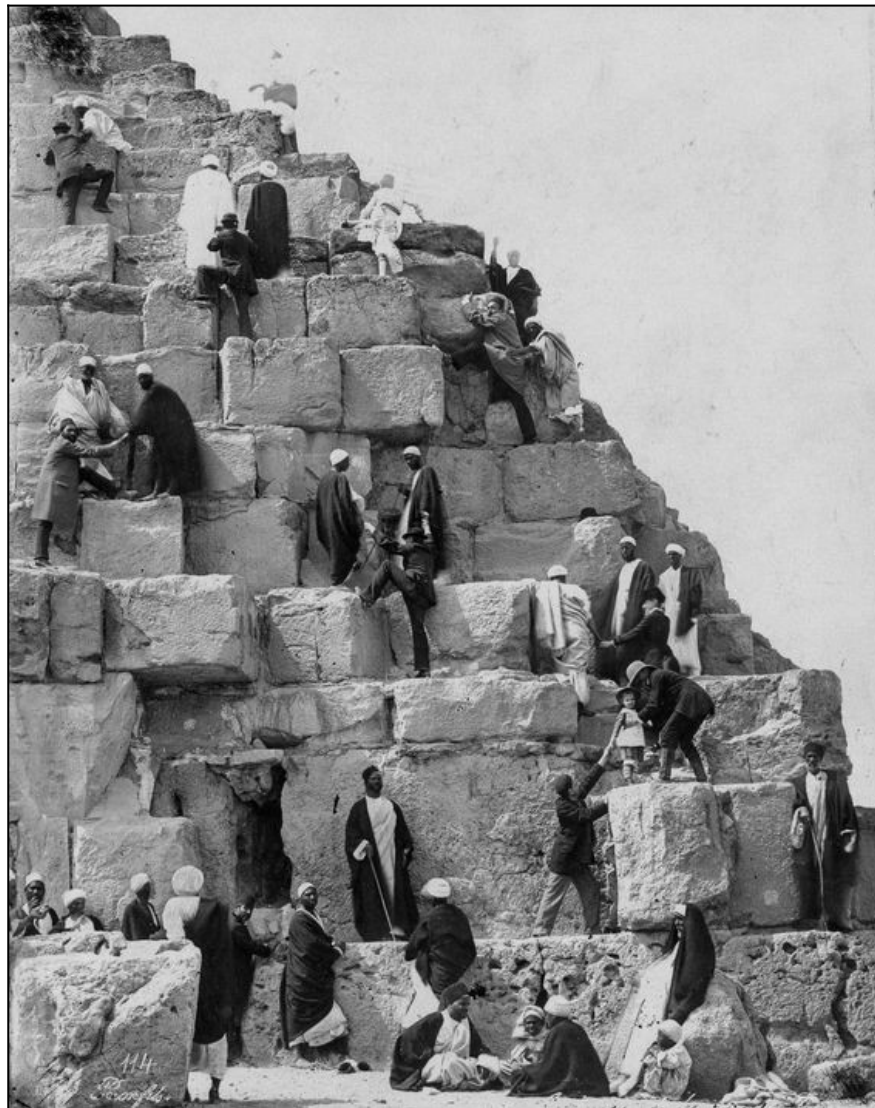
One can observe the composition of the Superior Eocene layer with which it would have been built.

(Situating in a military zone, we could not go there)

Fig. S4: Great smooth pyramids

2 pyramids of DASHUR (Bent Pyramid and Red Pyramid) and 3 pyramids of Giza (Cheops, Chephren et Mykerinos)

The large cyclopean blocks are provided by the Middle Eocene layers, piled simultaneously on the four faces of the pyramid, from a first pyramidion placed on the preexisting plateau. « It was first built with this shape; then they hoisted the additional stones with a machine made of short pieces of wood », Herodotus (see fig. 2). This means that this pyramidion (containing the Queen's chamber in Cheops' Pyramid) was not built with the « successive steps » that he describes for the rest of the construction. It is made before, in order to determine the shape, the slope and the rhythm of the placement, therefore the algorithm.



Notice on this photograph the NE angle of the pyramid of Cheops.

The first two levels are cut in the base of the plateau (all the way to the little girl).

Fig. S5: Abousir pyramids

Step pyramids made of small blocks that one can carry by hand. The blocks come from the site itself (Superior Eocene) with complements to make them smooth



The three pyramids of Abousir (North of the Saqqara plateau) are on the same Superior Eocene bed. Although they date of the Vth dynasty, therefore after the IVth dynasty ones, made with cyclopean blocks, they are built by steps, because of the small stones of their implantation site.

We can therefore establish the relationship between the shape of the pyramids and their respective geological bases via their different constructive methods. One can deduce the general fact that the construction methods were adapted to the characteristics of the rock base (small or large stones), and that this generated the shape. In other words, the characteristics of the materials provided by the rock layers imposed the adapted Method, which created the Shape. The shape of the pyramids does not depend on style, but it results from the employed method, dictated by the stones (large or small) of the geological layers.

Fig. S6: Text Pyramids

The prototype is the pyramid of Unas (Pyramid Text)

Unas' pyramid (Vth dynasty) is implanted immediately south of Djoser's funerary complex in Saqqarah. It belongs to the same Superior Eocene layer, "tafla", and Middle Eocene.

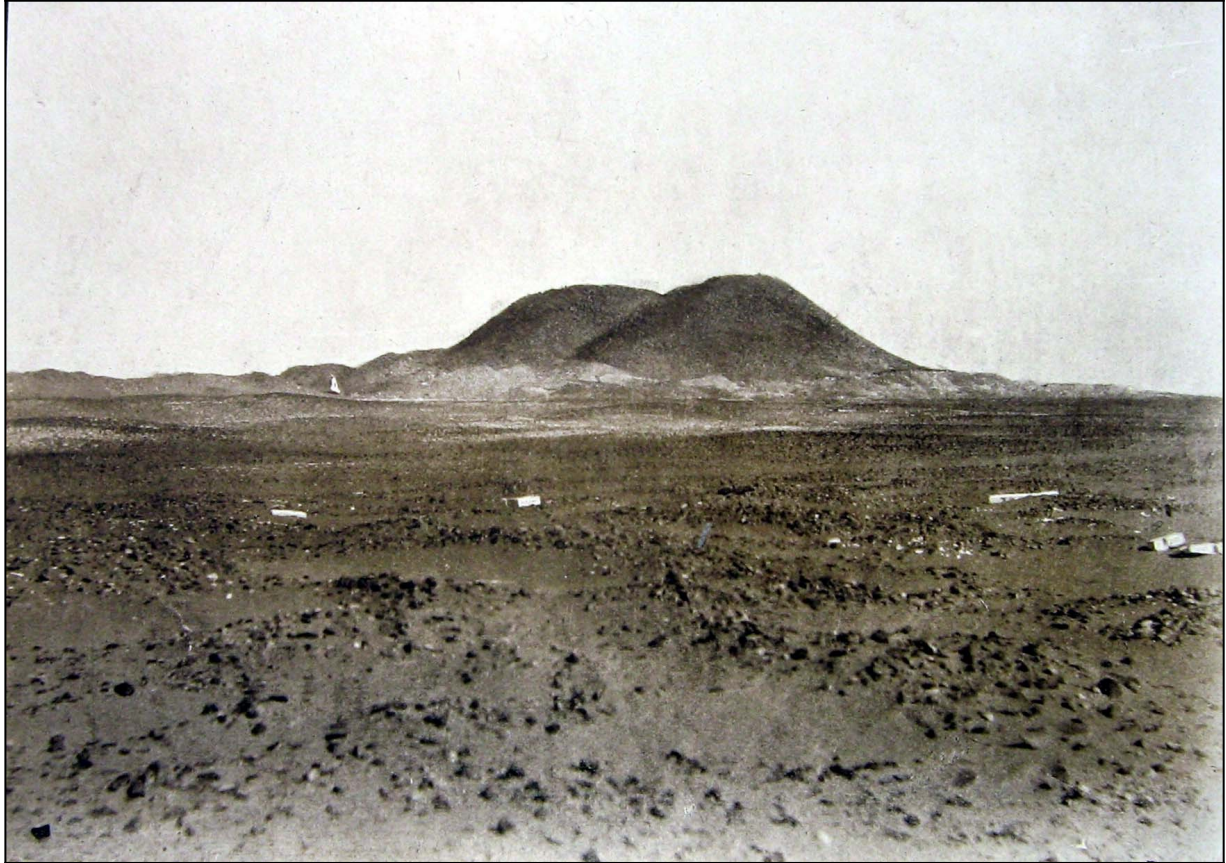


South West angle of Unas' pyramid

It is made of a core of small stones (Superior Eocene) exploited on the surface of the layer, itself resting on a bench of pebbles on Tafla. The core is surrounded by large "backing stones" coming from the underlying beds (Middle Eocene).

Fig. S7: Brick pyramids (XIIth dynasty)

They are all implanted on a pebbly ground, at the very limit of the alluvial flood plain that provided the material to make the bricks (Nile loam). Dried in the sun, the bricks were then transported on the construction site, at the closest point, but protected from flooding.



The brick pyramid of Sesostris III in East Dashour. In front, the flood plain at the time.

Fig. S8: Rhomboid Pyramid

View from the top, where one can see (in spite of erosion and of a partial slipping) that the blocks are stacked in a parallelepiped way, as headers, i.e. perpendicularly to each face.



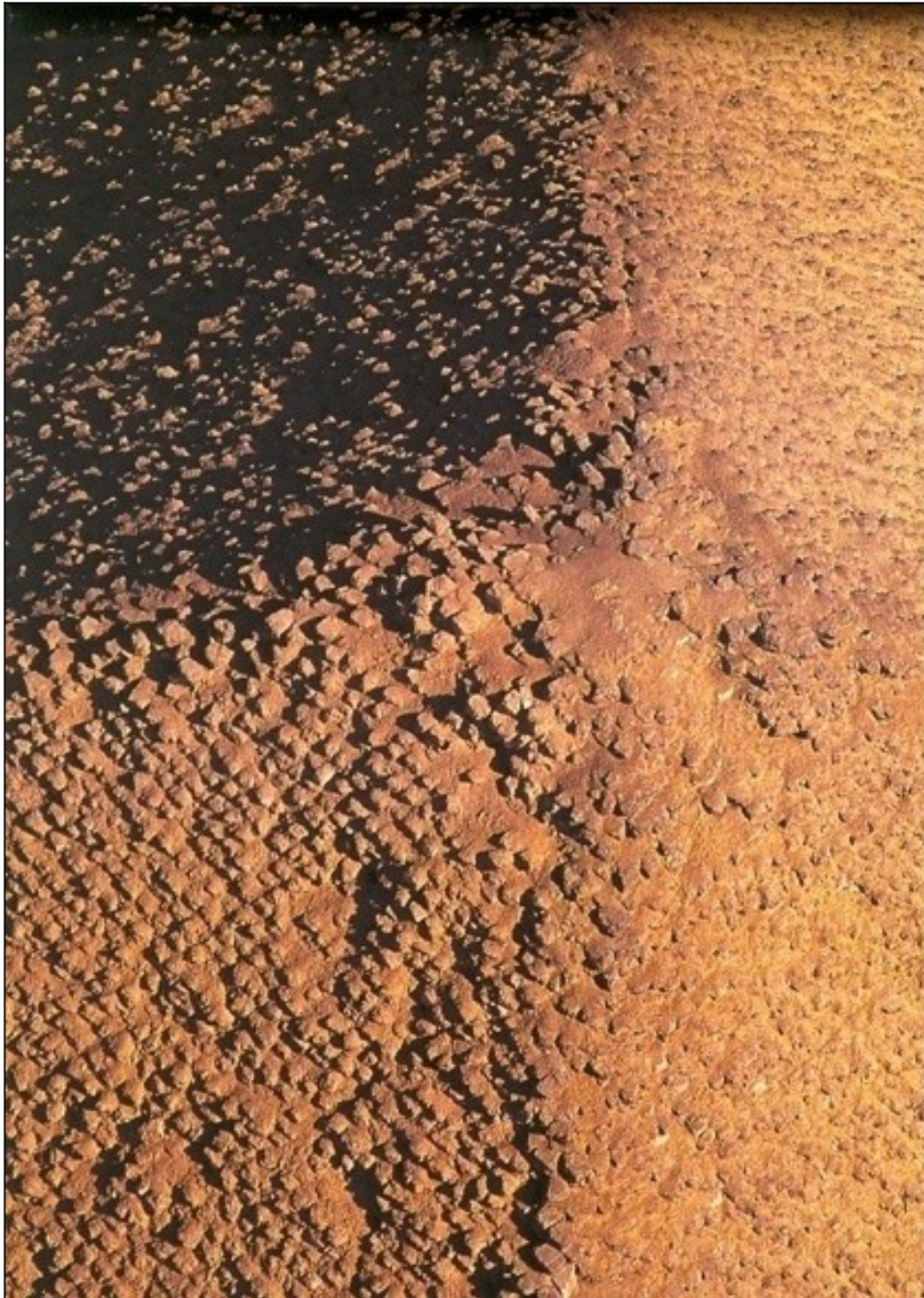
Photograph by M. Bertinetti for White Star, published by NGS in “EGYPT between sky and Earth” (2004)



The rhomboidal pyramid is also built in the center of its own quarry. One can see the ditches in the areas from where they took the stones. (Photograph by M. Bridges: *Egypt : antiquities from above* -Boston1996.

Fig. S9: Arrangement of the blocks "in the back"

View of the top and edges of the Red Pyramid (shade of stone), where one can see the organization of the blocks as headers, in spite of erosion.



Photograph by M. Bertinetti of White Star NGS in *EGYPT between sky and Earth* (2004).

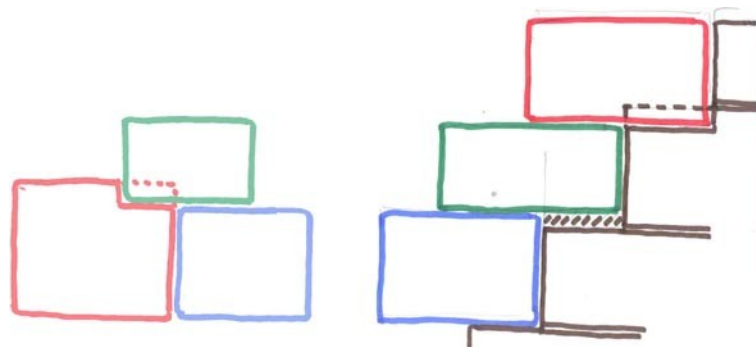
Fig. S10: Top of the pyramid of Cheops

View of the notches on each block, due to the horizontal arrangement with recesses that allows to place correctly one block (crossas) on top of two others (bomides) on one face of the enveloping cone as well as from one of the cones on another enveloping cone

These notches proof the use of the system of pyramidal accretion (**P. Crozat - 2002**).



Photograph M. Bertinetti/White Star éditée par NGS dans *EGYPT entre ciel et terre* (2004)



on one envelope

&

from one envelope to another

“Horizontal arrangement with recesses” (A. Choisy)

Fig. S11: Pyramids of Shaanxi - PRC. QED

They are made with earth (loose: silt earth, rich in limestone, fertile, made of fine elements easily transported by the wind, as in Shaanxi).

The earth was taken directly around the building. The topography and the distribution of the fields show clearly the extraction area.



Earth pyramids of Shaanxi in Xi'an - PRC

Here too, the pyramid starts on the original ground with a first « pile » which grows with successive envelopes according to an algorithmic logistics adapted to the material. It offers the ontological direct demonstration of the link between the materials and the site, adapted constructive method and building (pyramid on its own quarry). QED

* * *

Cf.#:

Cf.1: [CV of P. Crozat SEARCHER 2017](#)

Cf.2: [Engineering of pyramids 2017 DIGEST](#)

Cf.3: [Simulation pyramidal increase- 1997](#)

Cf.4: [Open Letter to Scanpyramids](#)

Cf.5: [Lettre circulaire à mes Pairs 2018 - in french\)](#)

¹ **Pierre CROZAT*** - French - Architect -Urbanist graduated from the Ecole Polytechnique Fédérale de Lausanne - EPFL (1971) (Prize of the Society of Engineers & Architects - SIA (CH) (1971), Dr. Engineer in Civil Engineering of the National Polytechnic Institute of Lorraine -INPL (F)/ National Higher School of Mines of Nancy - ENSMN (2002) under the title "*Le génie des pyramides*" (Congratulations of the Jury Chaired Dr. Hany HELAL); Thesis Director: Prof. Jack-Pierre PIGUET Director ENSMN and Prof. Thierry VERDEL, Director of the Environment, Geomechanics and Work Laboratory - LAEGO.

² **Thierry VERDEL** - French - Prof. Department of Geoenvironment /ENSMN (F), currently Rector of the French-speaking University Leopold SENGHOR of Alexandria (Egypt).

³ Specially the pyramid of Cheops, "the most enigmatic" because of its interior features: corridors, rooms and large gallery, which, as a result of our study, will be "the most revealing" of the Constructive System of the great pyramids.

⁴ **Biblical theories:** John Taylor, *The great pyramid : Why was it built and who built it?*, 1859; Piazzzi Smyth, *Our inheritance in the great pyramid*, 1864, et *Life and Work in the great pyramid*, 1865; Morton Edgar, *The great pyramid : its scientific features*; D. Davidson; Adam Rutherford, *Pyramidology*, 1972; Georges Barbarin, *Le secret de la grande pyramide ou de la fin du monde adamique*, 1936,

⁵ **Theosophical theories:** Marsham Adams, *The house of the Hidden Places* et *The book of the master*, London, 1845. Ralston Skinner, *The source of measures*, qui fait un rapprochement avec la cabale juive, clef ésotérique de la Bible ; H.P. Blavatsky, *Isis Unveiled*, 1931 ; Edouard Schuré, *Les grands initiés*, Paris, Perrin, 1961 ; Georges Barbarin, *Le secret de la grande pyramide ou de la fin du monde adamique*, Hadyar, 1936 ; André Pochan, *L'énigme de la grande pyramide*, 1971 ; Michel Claude Touchard, *Les pyramides et leurs mystères*, 1966.

⁶ **Astronomical theories:** Jomard, *Description générale de Memphis et des pyramides, accompagnée des remarques géographiques et historiques, ainsi que Remarques et recherches sur les pyramides d'Egypte, et Exposition du système métrique des anciens Egyptiens, contenant des recherches sur leurs connaissances géométriques, géographiques et astronomiques et sur les mesures des autres peuples de l'Antiquité*, 8 tomes en 9 volumes, Paris, Imp. impériale, 1808-1822 ; Le Père et Coutelle, *Observations sur les pyramides de Guiseh et sur les monuments qui les environnent*, *Antiquités, Mémoires*, t. 2, 1818 ; Abbé Moreux, *Les énigmes de la science*, 1941, et *La science mystérieuse des pharaons*, 1943 ; Richard A. Proctor, *The great pyramid*, 1888 ; Duncan Machaughton, *A scheme of Egyptian chronology*, 1932 ; Cotsworth, *The national Almanac*, 1902.

⁷ **Mathematical theories:**Richard Lepsius, *Über den Bau der Pyramiden*, 1843; L. Borchardt, *Die Pyramiden, ihre Entstehung und Entwicklung*, 1922; Jarolimek, *Der mathematische Schlüssel zu der Pyramide des Chéops*, 1890; Flinder Pétrie, *The building of a pyramid* , 1930 ; Hermann Reikes, 1907; K. Kleppisch, *Die Chéops pyramide, ein Denkmal mathematischer Erkenntnis*, 1921; F. Noetling, 1921 ; I.E.S. Edwards, *Les pyramides d'Egypte*, Tallandier, 1981.

⁸ **Frontal ramps theories:** Prof. J. Davidovits, *Ils ont bâti les pyramides*, Paris 2002, *La nouvelle histoire des pyramides*, Paris 2004 , *Bâtir les Pyramides sans Pierres ni Esclaves? La science défie les égyptologues*, Paris 2017 ; Prof. G. Demortier, 2004 ; et J. Bertho, *La pyramide reconstituée*, 2001

⁹ **Lateral or enveloping ramps (external or internal):** Louis Croon, *op. cit. (multiples rampes le long des gradins)*. Uvo Hölscher, *Das Grabdenkmal des Königs Chephren*, 1912 (*quatre rampes superposées sur une face*). Wheeler, *Pyramids and their purpose*, 1935 (*quatre rampes*). Georges Goyon, *Le secret des bâtisseurs des grandes pyramides*, 1983.

¹⁰ The step pyramids of the 3rd Dynasty have been little studied, except that of Djoser in Saqqarah by the Egyptologist- French architect J-Ph. LAUER, who thought it was an overlay of Mastabas. This vision is "formalistic" and not "constructive" We have demonstrated in the thesis (P. Crozat - 2002) in the chapter "Technical Continuum of Tumular Works" that the appropriate method existed from the first rural cleansing of the Neolithic.

¹¹ **Step pyramid turned smooth pyramid :** L. Borchardt , E. Guerrier, *Le principe de la pyramide égyptienne*, 1981 , *Les PYRAMIDES l'enquête 2006*.

¹² **Accretion of decreasing of walls:** H. Straub-Roessler, A. Choisy

¹³ **Algorithmic pyramidal growth:** Pierre Crozat- Ph.D (1990-2019), « *Système constructif des pyramides* » 1996, « *Le génie des (grandes) Pyramides* » 2002.

¹⁴ Photograph of the Neolithic Maes Howe tumulus of the ORKNEY (ORCADES) (north of ECOSSE) (more than 20 feet high and 100 feet in diameter) dates from the Neolithic (-5000 BP) is the most expressive prototype of the "vernacular" method: exploiting around the edge to abound to abound in the center. (Ed. NATIONAL GEOGRAPHIC - Review August 2014).

¹⁵ Myriam WISSA: "Old Kingdom's Building Stone in the Royal Funerary Complexes from Memphis and Letopolis : Typological and Lexicographical Studies" (Paris 4 Sorbonne.- 1995). This dissertation is a multidisciplinary research dealing with archaeology-Egyptology and petrography and stratigraphy (geology). Focusing on the nature and the origin of building stones used in the royal funerary complexes of the old kingdom and the reason of choice of the materials.

¹⁶ A. CHOISY, *The art of building among the Egyptians*, History of Architecture, Chapter II EGYPT - Ed. Inter-Books

¹⁷ Premier livre « SYSTEME CONSTRUCTIF DES PYRAMIDES » Pierre CROZAT - Ed. Canevas (F) & (CH) - 1996 - ISBN 2-8838-064-3-

- ¹⁸ M. RUHLAND: *Researches on natural fracturing of rocks (1969 - 1972) - Method of study of natural fracturing of rocks associated with various structural models*. Institute of Geology, Louis Pasteur University, F 67084 Strasbourg Cedex - Associate Research Team at C.N.R.S. "Structural geology and tectonic analysis". Bulletin of the Geological Society, 26, 2-3, p. 91-218, Strasbourg, 1973 (LOUIS-JEAN Imp., 1973).
- ¹⁹ Public lecture given at the CULTNAT / Smart Village / CAIRO on the 26/09/2017 by Pierre CROZAT.
- ²⁰ J. CUVILLIER, *Revision of Egyptian Nummulars* - Ed. Cairo, imp. Schindler, 1930. In-4, 372 p., Pl. (Memoirs of the Institute of Egypt.) (p.538).
- ²¹ 3D simulation of the paleo-topo-stratigraphy of the Giza plateau was carried out with the assistance of the Geoengineering Department of the Ecole des Mines de Nancy (Prof. J. SAUSSE and student Th. BURLETT) in 2015.
- ²² Institute of National Geography - IGN, Paris (F), established by photogrammetric restitution, well the digitized topographic survey of the plateau GIZEH: Giza Plateau Mapping Project directed by Mark LEHNER (AERA).
- ²³ As intuitively envisaged in "*CONSTRUCTIVE SYSTEM OF PYRAMIDS*" (p.143-144) Pierre CROZAT - 1996.
- ²⁴ SCAN PYRAMIDS is a Mission under the aegis of the Arab Republic of Egypt / Ministry of Antiquities, designed by HIP INSTITUTE Heritage-Innovation-Preservation and carried out by the Faculty of Engineering of the University of CAIRO.
- ²⁵ Committee (RAE) of famous Egyptologists-Archaeologists composed of Zahi HAWASS (EG), M. LEHNER (USA), R. STADELMANN (D) all following the rampant solution.
- ²⁶ See: OPEN LETTER (official) of P. CROZAT at 10/11/2017 to Dr. Hany HELAL, Prof. at the Faculty of Engineering at Cairo University, Dr. in Rock Mechanics and as such President of the thesis jury of Pierre Crozat about "The Engineering of the Pyramid" (2002) and Scientific Director of SCAN PYRAMIDS.
- ²⁷ P. Crozat in the "*Constructive System of Pyramids*".
- ²⁸ Jean-Philippe LAUER (1902-2001) a French architect, versed very early in Egyptology-archeology, has worked throughout his life on the site of Saqqarah (step pyramid of Djoser), he is the author of the "theory of the frontal ramp" of the great pyramid of Kheops in his book "*The mystery of the pyramids*" (Ed. Press of the City - France - 1988 - ISBN: 2-258-02368-8) and the report Height / $\frac{1}{2}$ Base = 14/11, an irrational number (anachronistic according to the History of Mathematics or even esoteric doubtful) in Chapter II "*Scientific Knowledge - The Geometry of Pyramids*" (p.227-237) that this study "CONSTRUCTIVE SYSTEM OF PYRAMIDS" fundamentally contests. An exchange of letters between J-Ph. LAUER (with his hand) and P. CROZAT - 1997) explain the reasons for this confrontation; it has been preserved and can be produced. This ambiguity corresponds to the esoteric current of a so-called Sacred Architecture.
- ²⁹ Michel SERRES (1930-2019) ("*The origins of geometry*" (Paris, Ed. Flammarion, 1993) is a philosopher, historian of science and mathematics, epistemologist and French man of letters, elected at the French Academy in 1990. His expression "Logistics or Algorism" which links the Logistics to the Algorithm (named after the Persian mathematician Al KWRITZMI of the Baghdad School - and his Egyptian colleague Al KAMAL, under the Caliphate of AL MAMOUN - the patron of the undermining of the Cheops's pyramid - in the 9th century) is a brilliant epistemological shortcut that suggests its source because, given the effectiveness of this undermines, it is very likely that Caliph was well informed!
- ³⁰ Plato's grave mistake in thinking that Zeno represented the knowledge of the Ancient Egyptians.
- ³¹ It is mainly the Egyptologists of the biblical, theosophical and astronomical theories.
- ³² These skills of the Stone Trades were brought through the collaboration with the J-P Companion. J-P FOUCHER ex-director of the Higher Institute of Research and Training of the Crafts of the Stone - ISRFMP in Rodez (F) and The Companion R. MOREL () Stonemason (Master of Art), members of the Association Œuvrière of the Companions of the Duty of the Tour de France AOCDF (headquarters in Paris - France).
- ³³ PYTHAGORA of Samos (6th century BC) mathematician initiated in Egypt is the author of the theorem of the Right Angle that bears his name (which the Egyptians practiced long before him), but also Series of Figured Numbers (so-called "sacred") or series of arithmetic suites (linear, triangular, square) that interest the subject of the construction of the Great Pyramids because they open to Pyramidal Growth and Algorism.
- ³⁴ NATIONAL GEOGRAPHIC "*EGYPTE between heaven and earth*" ©French edition - 2004 - ISBN 2-84582-133-6.
- ³⁵ WHITE STAR LLP has been the exclusive publisher of National Geographic books and guides for Italy since 2001. A prestigious American non-profit institution, founded in 1888, the National Geographic Society aims at scientific disclosure and education.
- ³⁶ Photography reserved for the former Secretary General of the Supreme Council of Antiquities of Egypt, Dr. Z. HAWASS for his album "*Treasures of THE PYRAMIDES*" Ed. White Star LLP - Vercelli (I) - ISBN 978-88-6112-382-3.
- ³⁷ This comment denotes the same syndrome as in "formalist" architects, to speak only of pyramid architects, that is, a phobia of the notion of "system", a system that they say would deprive them of their creativity.
- ³⁸ Auguste CHOISY, Engineer Polytechnician and Architect (1841-1909), *History of Architecture* - Ed. Inter-Books - Chapter II EGYPTE - Paragraph: Device, Details of The Execution of Walls and Massifs: p.28 and 29), describes the three processes used (with the corresponding sketch), in the construction of the

pyramids- "the device by set seats A (which corresponds to Chephren -NDR); B the B-drop-off machine (found in Cheops and Mykerinos - NDR - the most work-efficient equipment," he will say); C the device by successive veneer (which corresponds to the dime pyramids of Djoser - NDR).

³⁹ Edgar Nahoumsay MORIN (1921 - Paris) (*Introduction à la pensée complexe*, ESF Ed., Paris. 1990) is a French sociologist and philosopher. A thinker of complexity, he defines his way of thinking as "co-constructivist" by stating: "*I am talking about the collaboration of the outside world and our mind to build reality*".

* * *