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Architecture of the Great Pyramid of Giza Concept and Construction

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Abstract

Egyptian culture of the old kingdom was locally and regionally simple and efficient; belief was in the sky and humanism was regulated by Ma'at as the key concept in Egyptian mentality. **IUNU** was the capital of the black land **KEMET** where **"**IUNU UNIVERSITY" is located. Physics were well studied; was already known; the right angle triangle of members 3, 4, and 5 with the 53^o angle was in use. Supremacy was integrated on earth by multiple interpretations in architecture. The great pyramid of Giza was and still the best magnificent structure ever built on earth without having contemporary science's final word been said. Massive lime stone blocks are now arranged there in a huge massive number of about two and half million pieces; their weight could reach 6.5 million tons.

Conceptually there was a strong belief that symbolism connects hot spots on the Egyptian soil as it represented the known world, as well as the main stars were connected in multiple constellations on the dome of the observed sky. Pyramids of Giza plateau, Saqqara plateau, and Abusir plateau were all examples of that concept. Other pyramids of Iunu era were also related to the same concept.

Structurally the Giza axis coincided on the Giza plateau. Giza plateau was a part of the Moqattam plateau during the Eocene formation. Pyramids on the worked out surface of the plateau were built with the local lime stone. Pyramids' blocks were extracted, shaped and transported to its definite place within the precinct of the plateau. Chiseled pieces of stone - as waste from shaping blocks - were thrown out on the northern edge of the plateau.

Constructional perception of what and why the Khufu pyramid took that shape shows some facts; two hundred courses composed the total existed mass where each group of courses composed a layer. Each layer started with thicker course and ended in thinner ones. Higher layers got lesser courses. So far, one should start thinking now why there were layers; why thicker and thinner courses existed.

In the mean time as mortar was not in use by that time, pyramids –as in Saqqara- were formed in inclined walls, as shown in the adjacent photo. In addition, inclined walls must have formed the whole structure of Khufu pyramid.

Keywords

Pyramid; Old Kingdom; Egypt; Khufu; Iunu; Giza Plateau; Constallations

1. Forward

Egyptian culture of the old Kingdom was locally and regionally simple and efficient; had powerful software and hardware of the time, belief was in the sky, humanism was regulated by ethical values, controlled by Ma'at as the key concept in Egyptian mentality, and supremacy was integrated on earth with the interpretation in architecture.

Huge edifices with excellent aesthetical forms were well spread all over the great Nile's shores to show up that supremacy. IUNU was the capital of the black land KEMET and was its culture center; it meant the SUN CITY" where located IUNU UNIVERSITY which hosted a great number of sages and scientists of the superior region of that time. By then knowledge by large was the aim of the country, Physics were well studied, the pi (π) was already known, the right angle triangle of members 3, 4, and 5 with the 53o angle in use, stars in the sky were observed through the year, precise calendar of the year could be reached and many other vital items in life were established. All that magnificence of knowledge was manifested in architecture; the best known architect was HEM IUNU the responsible man for the great pyramid of Giza (fig.1).

Figure 1. HEM IUNU was thesuper-visor for the Khufu pyramid.

Till the present moment in the field of Egyptology most of the secrets of our ancestors in building pyramids are not yet all uncovered; neither modern science did say its word with confirm. In Egypt there are really a great number of pyramids that exceeds one hundred ten pyramids, well spread over the stable soil on the western side of the Nile. They extend in existence from south until they end at Giza plateau in the north, but we did not yet include all the structural differences of our concerned thoughts in the scientific agenda. Knowing they are there, a quite good number of considerations from art historians and historians starting Herodotus from the fifth century B.C. and until nowadays, discussed how the building material was imported and layered in situ, but again, there is no any collective agreement on any idea from them.

Famous Herodotus explained in book (Herodotus, 2016) after his visit, that the so called "Cheops" pyramid was constructed in a period of twenty years. To do that, he explained that a ramp was designed to elevate the imported blocks of stones from the eastern side of the Nile to the pyramid base level. Then by using levers Egyptians could arrange these blocks in superimposed layers. And that is really a simple naive explanation. To drag one piece of stone that weighed around ten or twenty tons, as most of the blocks were, on a horizontal path, not to say inclined, needed between 400 or 600 individuals. If that host of people were lined up, they needed to be hypothetically ten in a row for forty rows or sixty rows which at least needed an area of six meters by forty or sixty meters, and that is illogic. What about two and half million pieces that also included forty-five granite blocks of seventy tons each needed for roofing the king's room? If that hypothesis was to be considered, that means that the ramp they used must have been for four hundred meters long - or maybe one thousand meters as Herodotus said- with inclination one tenth to acquire a height of forty meters difference from the street level to the pyramid base. By that time the Nile bank was at the feet of the Sphinx and it was illogic to be used as a dock because its short distance. Even if the four hundred meters ramp was valid, it took six groups or twelve groups of pulling pieces up for one day. That means at least a period of five hundred years of hard labor needed to finish the mission of the three pyramids. If Herodotus considered the ramps discovered at the unfinished pyramid at Saqqara site was the prototype way to help constructing pyramids, one main criticism might be posed to the idea is that both sites and the building

material of Giza and Saqqara are different (fig.2 and fig.3).

Figure 2. Part of the unfinished pyramid at Saqqara. Mud bricks as a building material were handy to transport on ramps then piled in inclined to 75^o walls.

Figure 3. Stone courses of Khufu pyramid were of a material and scale clearly different from the unfinished pyramid.

One fact about Herodotus is that "*He is candid about acknowledging ignorance, and when versions differ he gives both*"(Herodotus, 2016). We know that "facts" he mentioned in his books were after different talks and hearsays he listened were not from authorities, by the meanings we know now. So far we have to be critical to his suggestions. But one fact should be considered as a start in the research, that is the stones that constitute the main body of the pyramid were of the local site (Ahmad Fakhry, n.d.).

For a huge edifice as this, having around two and half million units of stones, structurally well spread and efficiently piled in layers to support their existence and resilience to time, an effective suitable and well thought of management must have been executed. Here another hypothesis might be considered.

Giza plateau is full of interesting morphological attractive spots to mention, and to be considered. To the west of the pyramid group, comparing to other surfaces on the plateau, there is a smooth convexity surface with a surface at level +110 m which gives the impression of being managed by man not by nature. Within the convexity there is a slight continuous depression that visually leads to unperceived valley between the second and the third pyramids to, with no doubt, drain the rain falls towards the Nile valley. Another interesting fact in the site is the presence

of a 3^o inclination ramp which was surely used to transport blocks from the high levels on the convexity to the lower sites; it is located to the north of the second pyramid measuring six meters wide by 200 meters long, with a longitudinal groove in the whole length. To the north of the plateau there is a huge amount of debris and remains of stone cutting and shaping procedures during the work, resulted in pieces that covered the whole northern edge of the plateau. Within the plateau there are five distinctive levels: apart from the convexity level +110m, the base of the greater pyramid is at +60 meters from sea level, the second is at +70 m, and the third pyramid is at +80m; the level at the feet of the Sphinx is at +20 where the waters of the Nile were overlooked by the Sphinx. So the puzzle that has to be looked after lies between these levels: +20, +60, +70, +80, and +110 meters. The most important fact to discuss, but not least to mention, is that the building processes in the Old Kingdom did not use any cementing material.

The Giza plateau was, in ancient times, geologically connected to the Moqattam hill on the other side of the Nile (Gamal Hemdan, 1984) (fig.4), crossing the site of what is now the capital Cairo. The top level of the Moqattam hill is now +200 m. The top level of the Giza plateau must have acquired a level hypothetically close to the Moqattam surface level, i.e. +200 m, or so. The geological formation of both sites, the Giza plateau and the Moqattam hill, is composed of a "*cretaceous nucleolus amid an iocenean formation*" (Gamal Hemdan, 1984), an action happened when "*Abu-Rawash concave cap mass was transposed upside down in the late upper cretaceous, resulting in a solid cap well exposed on the surface*". Amid that process, the site was formed as hill heights along with convexes of the vallies, keeping an "*axis running from the eastern North to the western South*". That axis almost coincides with the axis connecting the centers of gravity of the three pyramids. "*The iocenean formation of the site is mainly composed of two strata, one higher and one lower. The lower stratum is identified as denser and more homogeneous*." And so far, the Nile valley bisected, after the ancient changes, that formation, one on its east and the other on its west, forming two heights overlooking it. The elevations of both sites must have stayed the same, or at least relatively the same. Here starts the hypothesis of the site management and the system of constructing the pyramids on the plateau.

Figure 4. thecontinuity of Moqattam plateau with Giza plateau that was before the historicalsplit.

The fact now that the surface level of the area to the west of Khufu pyramid reaches +110m does not mean that it was the original height before its construction. Moreover as up mentioned, the other part of the formation- the Moqattam - on the east of the Nile is having an elevation +200m. Having this fact, and investigating the formation of the stones of the building material of the pyramid and the ground surface where pyramids were built, one could easily find that the former one was chosen from the upper stratum of iocenean site while the latter one is the original lower dense stratum of the iocenean which was used as a base for the structure.

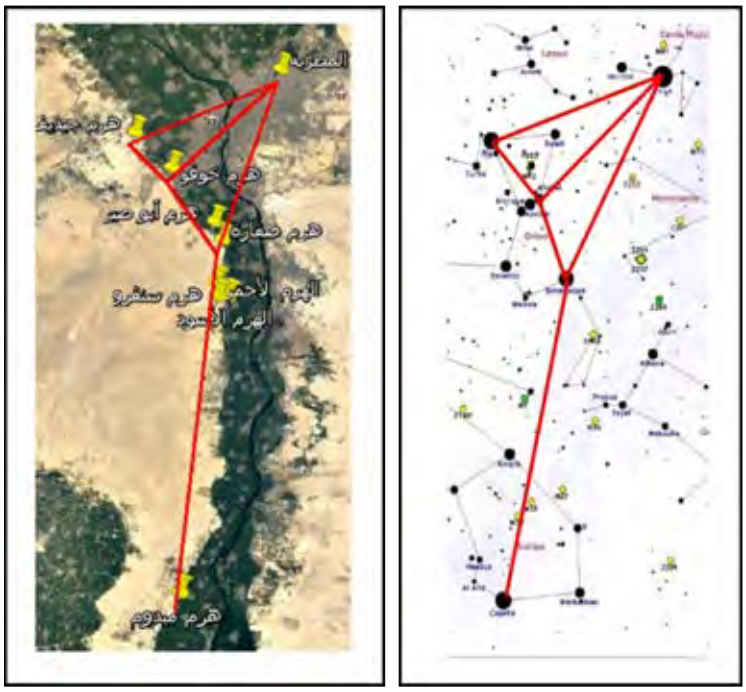

Figure 5. Map including the Iunu pyramids as it wasidentically presenting the map of the five stars in the three constellations.

2. The Concept

In the **IUNU** era of **KEMET,** strong connections were considered between the visually perceived sky's components and the conceived world of power concentrated in Egypt. God was believed to be one; he dwelt unseen in the sky. He could grant a chosen woman a boy or a girl. The woman who got pregnant gave birth to a royal king or queen. Their status could have been considered sacred. As in philosophy every fact should have had the five questions to be answered: what, why, how, where, and when. By that philosophy every fact had a symbol representing it. Kingdoms had symbols over the kings' heads, the god was symbolized in the character "Khnom", Iunu was symbolized as star "Sirius" which also indicated, by its first yearly appearance in the east, the New Year and the beginning of the inundation, by that time, on the fifth of July each year. Kings' souls (Ka) were believed to leave after death to certain stars from which they return on the time of resurrection. Accordingly pyramids were symbolized and presented by stars in constellations in the sky, so maps of both these stars and the pyramids of the period are identical (fig.5)[1] . Iunu was presented as Sirius, Saqqara site as Betelgeuse, Khufu pyramid as Alnitak, Djedefre's as Rig, Khafre's as Ainilam, Menkaure's as Mintaka, Meydum's as Capella.

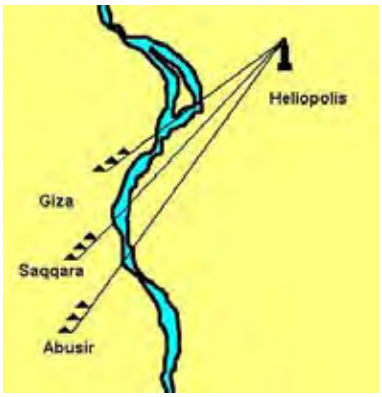

Figure 6. Three axes were visually connecting Capital Iunu to the sites of Giza, Saqqara, and Abusir.

In some idea (Magli, 2013) there was a hypothesis telling about a visual connection between Iunu and some

[1] Author's drawing on Google and stars' maps.

pyramids of the time, upon which the terms "Giza Axis", "Saqqara Axis", and "Abu Sir Axis" appeared in literature (fig.6), which the latter axis was considered the last towards south because of the existence of the citadel hill as it hindered the visual path; the visual connection of Meydum to Iunu was interrupted by the Moqattam hills (fig.7)[2] , though Meydum-Iunu axis took the right proportion as Capella-Sirius (fig.5). It could be concluded so far, that it was not the ***visual axis*** as much as it was the ***value axis*** that connected the pyramids to the stars.

Figure 7. The value axis connected pyramid Meydum to Capital Iunu.

After taking the decision of choosing sites for Snofru's pyramid- Meydum- to correspond to its related star, decision of choosing pyramids' sites for Khufu and his three successors reached the selection of the three stars in the Orion's belt. Accordingly and with respect to the proportions of distances among the corresponding stars the three pyramids' sites were chosen on Giza plateau, laid on the Giza axis that was also visually connected with Iunu.

2.1. Structurally speaking

The huge weight of each of the three pyramids should have had its line of stresses to safely go all the way from up down to the main crust of the earth. That is why the Giza Axis should have coincided with the axis of the geological convex formation of the Giza plateau (fig.8)[3] . Here one should say it was the perfect appropriate choice correlating structure, astronomy, geology, geography, and belief all together in the structure process. The group of the three pyramids' masses that could reach 13.5 million tons was distributed on the axis of the plateau (fig.9)[4] . In the mean time, to have the three pyramids visually well perceived from Iunu, their bases' levels acquired 10 meters difference from each other i.e. Khufu's was on +60m, Khafre's on +70 m, and Menkaure's on +80 m. By mentioning that, the sum of masses of the pyramids almost reached 13.5 million tons, it should be said that as this was the dynamic weight, the equivalent static weight in place prior to the construction was five or six times, i.e. 67.5 or 81 million tons. That was the net weight of the blocks but, if we consider the wasted ruble resulted from shaping the blocks that number could easily have been doubled i.e. around 160 million tons. If the plateau was considered as the area between the contour lines of + 60 and +80, then the area was 797692.5 square meters. That means that the height of that area could have reached level +160 meters or higher. So, that height was used as the building material in situ for the pyramid. Having that elevation of the original plateau, the logic tells the fact of transposing the huge masses extracted from the high levels to levels below, and ramps were used to roll blocks down. There is an example of such a ramp in front of the second pyramid which is a point to be discussed down.

[2] Author's drawing on Google map.
[3] Author's drawing.
[4] Author's drawing.

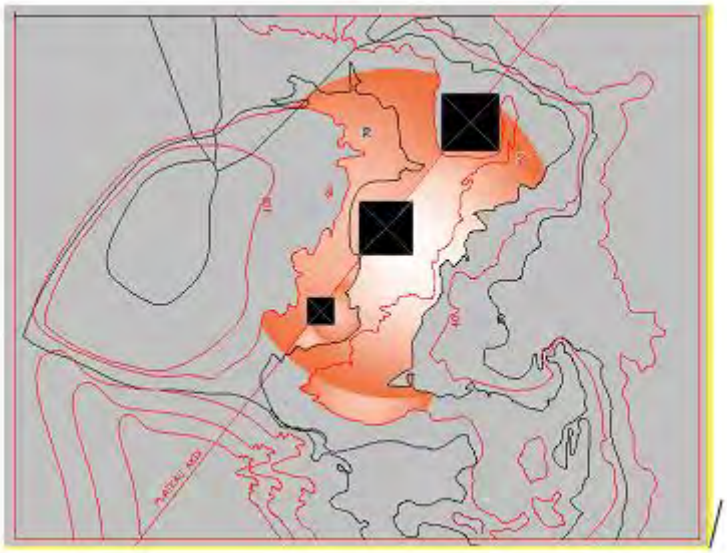

Figure 8. the three pyramids' axis coincided on both theGiza axis and the plateau axis.

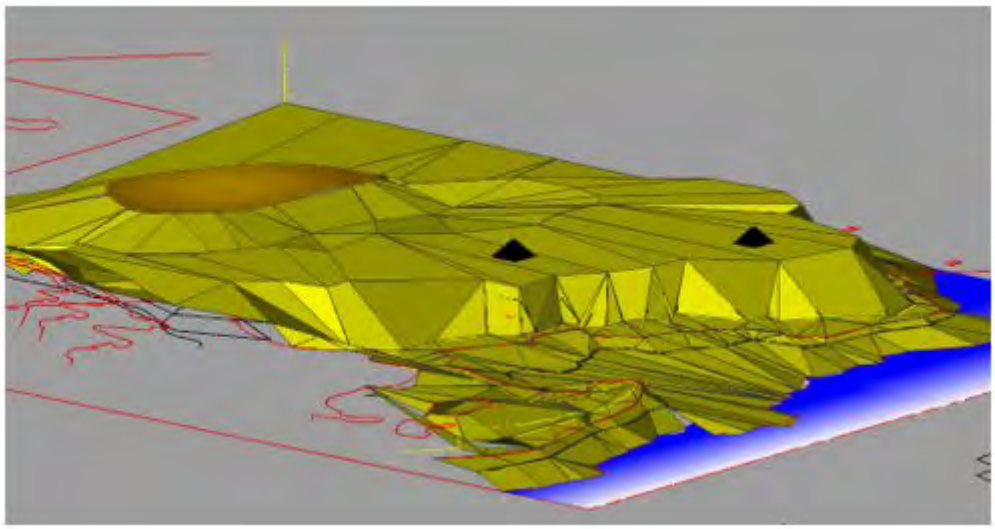

Figure 9. the original Giza plateau as imagined, whilekeeping the pyramids in place to show the static mass of the original geologicformation

3. Site Management

As the upper Eocene stratum of the plateau was used to get blocks from; blocks were to be shaped into the suitable sizes for the building. The visible courses of the pyramid are of all different thicknesses that ranged between maximum 153 cm in the second course to minimum 46cm in the eighteenth course. Actually, there is a repetitive sequence of layers each of which is composed of some courses started with a thick course and ended in a thin one; there are eight of them (fig.10)[5] That process was repeated until the course number 120 at a height of 90m from the base level. That means that the periodic procedure of layers firstly demanded easy way for supplying heavy blocks; when that way got tougher blocks got lesser in weight and thickness. If one considers the ramp in front of the second pyramid as the prototype for transporting blocks of stones from a high site to a lower site, then it is logic to suggest that there were eight successive ramps well distributed in site to transport blocks to the successive layers mentioned before. Courses over the height 120 m did not have the possibilities of getting heavy blocks that is why they were all around 0.5 m thickness. If that was the genius way of accumulating the mass courses of the

[5] Author's drawing.

pyramid, then comes to mind the second interesting point which is the bonding principle on which the huge mass got coherent.

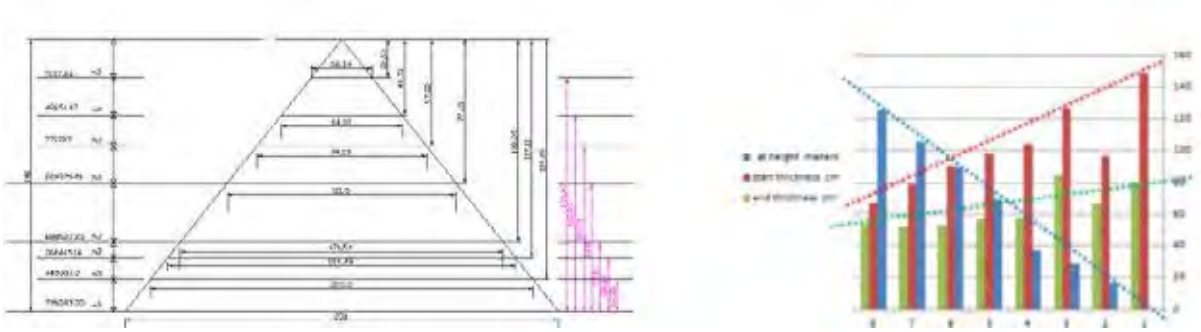

Figure 10. Eight layers in successive heights formed the mass of the pyramid. The blue dotted line indicates levels of layers, the brown indicates first courses' layers related, and the green indicates the last course of each layer. Dotted lines show the decrease in thicknesses as layers'courses get higher levels in the pyramid.

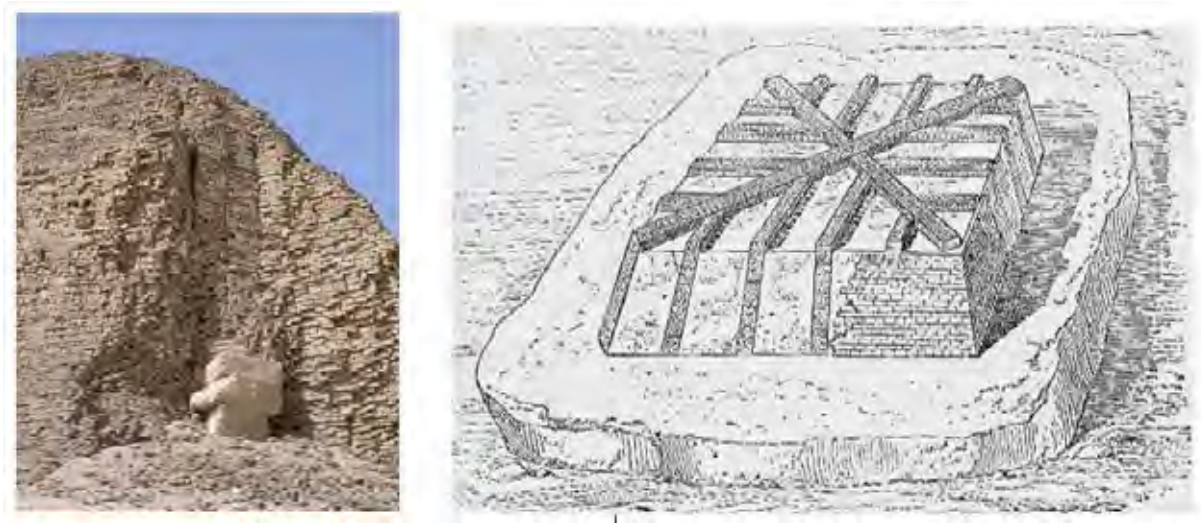

Figure 11. Illahun pyramid drawing showing the main carcasswith leaning walls in between.

4. Structural Concept

Looking for the cementing material that was supposed to act as a bonding material between the blocks and the layers together, one can easily find nothing. Looking up for the way older pyramids used, it was found that the preceded Djoser's pyramid used a very effective and natural power that gave its shape the resilience that lasted now for 4647 years (fig.11). The genius method used was mainly to construct leaning walls in the four sides of the pyramid, the slope was directed to the center of the pyramid with an angle 75 degrees. There was no other material more than stone blocks except small pieces of stone to adjust the needed leveling of the courses. This was the system of supporting the structure all over the edifice. That was actually the system of the old Kingdom in the industry of construction.

Figure 12. Leaning walls formed the whole structure of the Saqqara pyramid.

In an example in Illahun, although built in the twelfth dynasty by Sesostris II, the structure of its partly ruined corner shows the details of how the walls were designed. There is double wall acting as diagonal for the structure, then there are two flanking inclined masses of courses acting as the sides of the pyramid. As a key stone to prevent the structure from sliding out, blocks of heavy stones were planted around the core. A drawing (Perrot, 1882) shows its design in axonometric presentation (fig.12). The structure here presents a carcass of main vertical walls in almost horizontal courses, and leaning walls flanking each of them on both sides, acting as support and filling.

Nowadays, leaning walls are used in retaining walls to support the horizontal thrust of the earth at the back. It could be on both sides of a highway. Leaning walls of loose bricks is actually the most practical, most safe and most stable condition under dynamic effects as vibrations or earthquakes. Leaning sheets of glass or leaning glass windows are best to be transported on trucks. Even leaning piles of bricks are of best case to keep until used (fig.13). All what is needed is to precisely keep inclination the same throughout the process of construction.

For a pyramid with two crossing walls and four leaning walls on the four sides the structure was held in place. Each block in each wall had its weight acting vertically, and since the block was inclined, the acting weight was to be analyzed into two components, one along the inclined plane and the second component acted perpendicular. By that fact each and every block consolidated the pyramid by its perpendicular force acted towards the center. Here we had a solid, fixed and stable structure that proved a positive resilience to all the negative natural environmental effects. In Saqqara pyramid the inclination of all the walls in the whole edifice was 75^o which is supposed to be the same in Khufu. From this point research could proceed in discussing the Khufu Pyramid case.

Figure 13. the way to keepblocks together safe in a dynamic environment is to have them on an inclinedplanes.

Hem Iunu the architect must have used all the experiences he acquired from the preceding pyramids. He had lots of privileges in his job; the unique convex site, the big masses of stones that could be easily handled, and moreover there was no more possibility for another pyramid to share with him the site. As the main concept of building was to have stone blocks leaning to the inside, the rock base of the pyramid must have acquired the same Principle (fig.14)[6] . It is suggested that the base was divided into four triangles slightly inclined towards the center.

Thinking of the management how that huge mass of loose heavy stone blocks characterized by superimposing more than two hundred courses laid in eight complexes layers was executed, bearing in mind the usage of ramps, morphology of the site should be clear imagined. Huge heavy blocks were extracted from the same site, Giza plateau. They were much heavier than those of any previous pyramid. Previous pyramids were designed on almost horizontal terrains that needed ramps to bring small blocks up; on the contrary the three pyramids of Giza were chosen on a super high already plateau which needed another means of transporting the blocks. The genius architect was to use the upper part of the plateau to build on the lower part using ramps to bring blocks down.

[6] Author's drawing.

Blocks of the higher cracked stratum were to take shape and be adjusted to be built on the same relatively height in the pyramid, and so did with each of the eight layers; the process to be explained next.

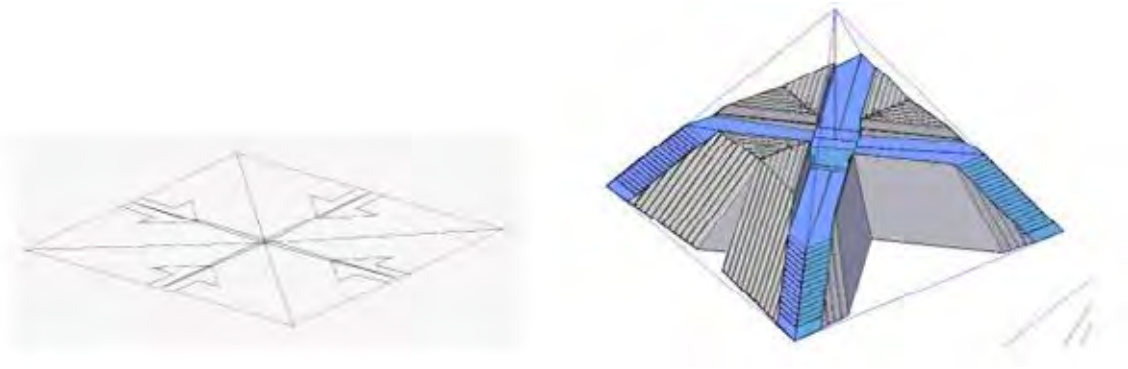

Figure 14. Khufu pyramid structure composed of two crossing diagonal walls encountering eight leaning to them walls; its base was divided into four inclined planes.

If considered the natural setting of the plateau as raised convex land, different levels must have been initiated to be eight levels corresponding to the eight layers of the pyramid; each of which to be connected with a sloping ramp to reach the south western corner of the pyramid on its related level. That corner was most probably the active corner because the other three corners were on the edge of the plateau. The concept (fig. 15)[7] behind that was to remove the upper part of the natural formation of the plateau, in the pyramid's site, and put it aside on the same level where it was extracted. On that site blocks were to be shaped and worked out to be ready to be sent back to its relative place in the structure. The procedure was to be repeated for each level till the lowest one.

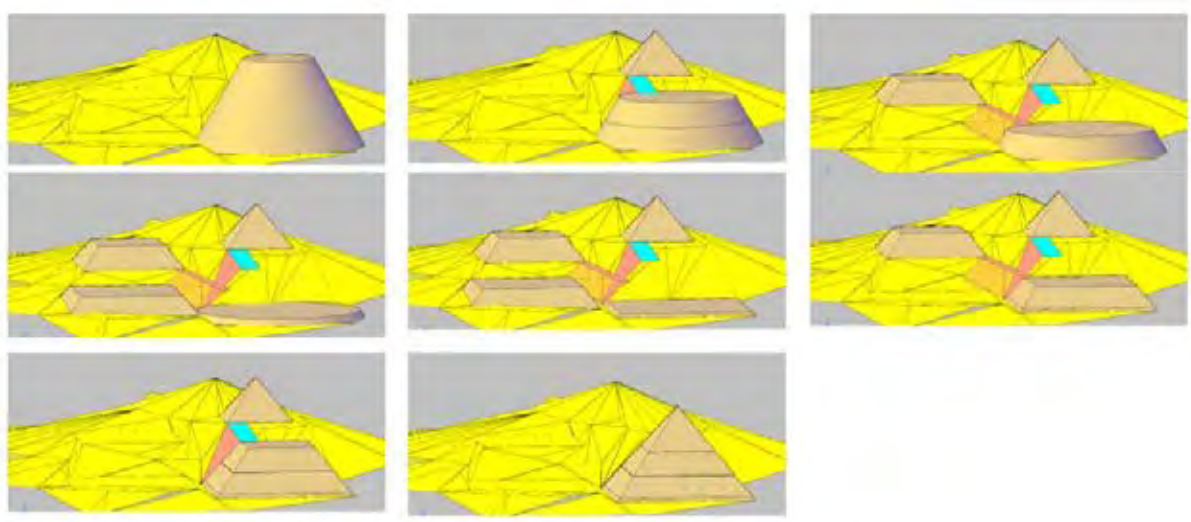

Figure 15. steps in executing the concept used for thelayer system in building the great pyramid of Giza.

Moving rough blocks of stones should have had ramps ready to move down from the natural site where they were cut to the working site, and then after they were already taken form in the working site they were to be rolled down the ready ramp to the pyramid in its relative place in the structure. The amount of work needed to accomplish that mission was lessening by getting higher. 30% of the pyramid volume was already acquired by the height 15 meters; 52% by 30 m.; 82% by 50 m.; 97% by 100 m., and only 3% of the total volume was embodied on the last 46 meters (Lehner, n.d.). At level 50 meters, after almost finishing 80% of the volume, forty five red granite blocks each weighing around 70 tons were brought to be used for the composite ceiling of what is called "The King's Chamber". That massive amount of stones could not have been brought to place unless ramps were used to bring them down through the Ma'ady plateau and then to the Giza plateau then to the site. If preceding experiences in

[7] Author's drawing.

building pyramids were to be considered, this Khufu pyramid must have two diagonal crossing walls flanked by inclined to 75^o walls (fig.16)[8]. As up mentioned, to have the principle of gravity working in bonding the stone blocks all over the building together, it is suggested that the rock base of the pyramid was divided into four triangles slightly inclined to the centre.

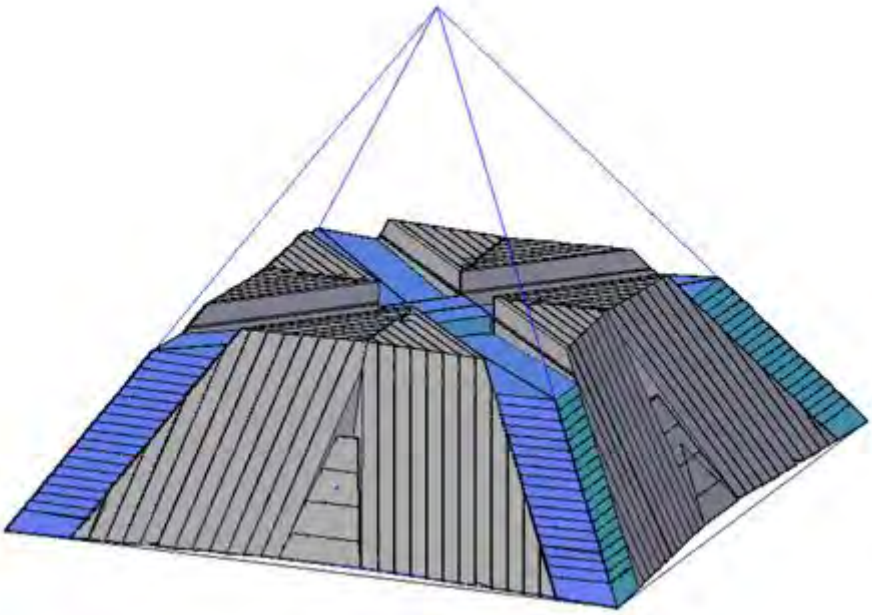

Figure 16. Drawing shows the pyramid under construction, as imagined by the author. The blue color indicates the horizontal layers of the crossing diagonal walls. The grey color indicates the leaning walls at 75^o on the crossing walls.

That way might have kept the whole loose stone edifice compacted towards the center. The process needed the best accuracy in cutting stone, preserving the same thickness all the way for every course to maintain the overall shape as we see now. It might be worthy to mention that the highest plane on the top of the pyramid is composed of one even plane of well arranged blocks of stones of the same thickness, loaded by seven free blocks.

When it comes to the grand gallery design with its spacious space that measured almost eight meters and half in height and forty seven meters in length, the architect chose to design it in a middle vertical plane between the two opposite inclined walls of the northern facade (fig.17)[9] . That again was the best structural choice for the grand gallery, because of the diverging horizontal thrust on both sides as a result caused by the two symmetrical inclined walls. Function of that gallery might be out of the scope of the research.

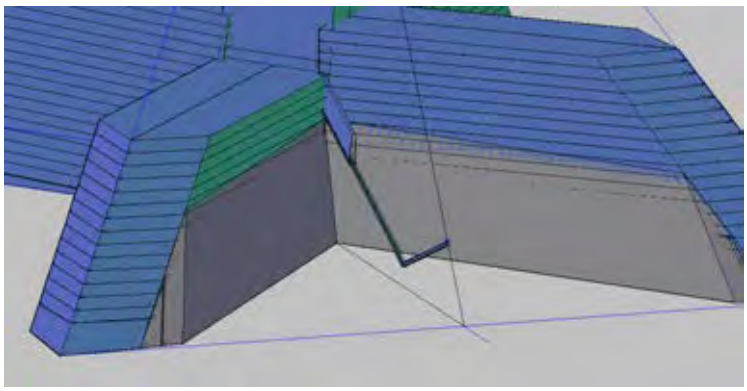

Figure 17. the grand gallery in Khufu pyramid as designedin the middle between the two opposite inclined walls on both sides.

[8] Author's drawing
[9] Author's drawing

5. Conclusion

The three main environmental factors – the eco sphere, the techno sphere and the socio sphere - were dealt with in a complete harmony to execute one of the best wonders of the world, the Great pyramid of Giza. Ecological considerations such as geology, morphology, geography, and astrology as one third of the equation were balanced with the ultra techno sphere of the forth dynasty, and all were controlled by the social beliefs MAAT and the behaviour of the Egyptian people. Gravity as one of the main Physics' laws was the main factor that kept the magnificent edifice in place and at that height all that elapsed time. No error work was the second factor in the building. The scientific basics were the appropriate infrastructure for the architectural aesthetics of the pyramid.

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