On Pyramid Building

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It is well known that the pyramidal structure is not unique to Egypt. The Mesopotamians witnessed the development of the ziggurat, and the Mexican pyramids of the moon and the sun are both very impressive. Although it is obvious that it took a great deal of dedication, organization, and intelligence to erect them, these structures are stepped and truncated; they are pyramidal only as a general description. Therefore, it is not difficult for someone interested in the subject to think of the manner by which they were built.

In contrast to these, the Egyptian pyramids are unique in several respects: their orientation, precision, and the size of the building blocks. Perhaps most impressive is the method of building which enabled the architect to encase each with four smooth sides that met at a point in the sky—a true pyramid.

In order for the ancient engineers to erect these structures, two primary problems had to be overcome: the first was to raise the stone to great heights and the second to place the stone in position with accuracy. The above statement seems obvious to anyone who has even a casual interest in the subject; yet, of the theories offered to date, the solution to one of these problems appears to cancel out the solution to the other. To be specific, in any of the construction ramp theories, by covering one or more of the faces, the means to lift the stone becomes the very thing that prevents accurate measurement of the pyramid.

In order to have four faces meet without twist, at a point almost five hundred feet in the sky, while maintaining a constant batter, it is necessary to measure the structure, as it rises, with the utmost accuracy. No diagonal measuring lines, datums, squares, or plumb lines, no matter how cleverly devised on paper, could possibly have served, without the assistance of the human eye, to observe the entire undertaking. For, if the pyramid is completely hidden as it rises, any error in batter or twist could become cumulative. If so, it might not be observed until the hidden faces are exposed when the construction ramp is removed at the end of the building process. It will be shown that in any ramp theory, not only the ramp face, but all four faces, are hidden. When the faces of the pyramid are finally made visible, it would be too late to make any but the smallest correction.

In the perpendicular ramp theory, it is postulated that the ramp, bearing on one face of the pyramid, rose with each course laid. To maintain its gradient, it would have been lengthened as the height of the courses increased. In addition, the pyramid would have been built from the ground up, one course being completed before the next was placed upon it.[1] While the face that contains the construction ramp would have been accessible to the workers, the other three would not. The presence of bosses on the roughly dressed casing stones shows that these, at least, were put in place from the outside, in the traditional Egyptian manner.[2] In order to do so, it has been proposed that foot-hold embankments were added to the remaining faces. These embankments would also have risen with each course, and, as a result, only the uppermost course would have been visible as the pyramid rose.[3]

[1] I. E. S. Edwards, *The Pyramids of Egypt* (London, 1961) 221-22.
[2] Ibid., 227.
[3] Ibid., 222.

Any discussion of this subject should also include an analysis of the possible materials that might have been used to build the construction ramps. Wood was used for small works, such as tools, furniture, and boats, but it was largely an imported material, and in short supply. Considering the vastness of the ramp and its need to bear great weights, wood can be eliminated as a possible building material. Burnt brick can also be eliminated, as it was not employed by the Egyptians until Roman times.[4] Sand cannot have been used, for if we consider the height to be attained and the angle of repose, the size of the mound needed would dwarf the pyramid. Therefore, the only materials available for the ramp, in the Old Kingdom, were sun-dried mud brick and stone masonry.

According to Petrie, the maximum height that a mud brick ramp can attain is approximately 380 feet. Beyond that, he feels, the brick would crush of its own accumulated weight.[5] Petrie also realizes that the ramp, being made of mud brick, would not support weight near its edges and, if continued to the top, would run out of work space, for it bears against the face of the pyramid which narrows as it reaches the apex. If made wider than the face, it would require an immense amount of earth as a backing—all clearly unacceptable to him. His solution to these problems is to complete the last one hundred or so feet, to the top, by means of a zig-zag stone ramp and, when that runs out of space, he suggests a method of levering up the stone from pits left in the pyramid. Unfortunately, this method seems unworkable and is unsupported by historical evidence.[6]

In addition to limiting the height of the construction ramp because of its own weight, we must also add the considerable weight of the stone to be transported upon it. We would therefore be prevented from even reaching the height limits set by Petrie.

Still to be considered when building with mud brick, is that air passages must be left in every few courses, for there is the problem of drying and cracking to contend with.[7] While the holes left in the ramp may help to alleviate one problem, they raise another. That is, the load-bearing capacity of the ramp is further reduced.

While it rains infrequently in the desert, when it does it can be torrential. Herodotus said that the pyramid took twenty years to build. In that span of time, the chance of it having rained is almost certain and any building method must therefore allow for this possibility. The accompanying expansion and contraction of the brick, together with the effects of the cutting winds, present problems that must be accounted for when using mud brick as a building unit. We can therfore see that Petrie's theoretical 380 foot limit has to be once again reduced.

In addition to the problems presented by the use of sun-dried mud brick as a building material, we must consider a problem that it shares with any type of construction ramp; namely, some of the pyramids were enlarged during the building process. As an example, consider the pyramid at Meidum.[8] It went through the enlargement process three times and would therefore have required the ramp and foot-hold embankments to be erected and dismantled three times—an overwhelming thought.

In summary, I believe that mud brick cannot be seriously considered as a building material for a perpendicular construction ramp.

The only other building material available to the ancient Egyptians was stone. Building with stone is very time-consuming; for, as Herodotus reports, the causeway of stone leading to the plateau was 3000 feet long, sixty feet wide and forty-eight feet high and took ten years to build.[9] Although this report can only be used as a general guideline, to have built a stone construction ramp to the top of the pyramid with a gradient of 12 degrees would have required a ramp over one mile long. The height of the ramp, 481 feet, is ten times that of the reported causeway. Therefore, the building time for the

[4] A. Lucas, *Ancient Egyptian Materials and Industries* (London, 1962) 50.

[5] W. M. F. Petrie, "The Building of a Pyramid," *Ancient Egypt* (1930) part II, 35.

[6] Ibid., 36.

[7] S. Clarke and R. Engelbach, *Ancient Egyptian Masonry* (London, 1930) 210.

[8] Edwards, op. cit., 65–66.

[9] *Herodotus*, II, 124, translated by J. T. Wheeler, *The Geography of Herodotus* (London, 1854) 392.

ramp would far exceed that of the pyramid. This would be clearly unacceptable as the building time for the ramp, alone, would extend beyond the Pharaoh's lifetime. Here again, it would be an even more overwhelming thought to contemplate the use of cut and fitted masonry for a construction ramp, considering the three enlargements of the Meidum pyramid.

For these reasons, I believe that we can rule out cut and fitted stone as the building material for a perpendicular ramp. Because we have no further choices for building material, we must conclude that the pyramids were not built with any form of perpendicular ramp.

Another type of ramp has been suggested as the building means by Dunham—it is generally referred to as the spiral ramp.[10] It seems like a logical alternative; but, on close examination, several aspects become very troublesome. The first problem to be considered is that, as in the previously discussed theory, the spiral construction ramp virtually encases the entire pyramid, making accurate measurement practically impossible.

Another point to be mentioned is the manner in which two- to three-ton stones can be manipulated around the multi-cornered ramp. Dunham suggests a method of erecting a post at the corners and bending the rope around it in order to transmit the pull 90 degrees.[11] This is very difficult to accept, for the vectored forces generated by the weight of the stone would more likely upset the post. In addition, think of how the fifty-ton chamber-blocks could have made the same journey—again, a possibility that cannot be seriously considered.

Finally, Dunham recognizes that any form of spiral construction ramp must be supported on steplike casing stones in order for the ramp to interlock with the pyramid. He also suggests that the casing stones ". . . would have been dressed back progressively from the top down as the construction ramps were removed, and when finished the pyramid would have presented a smooth even slope from top to bottom."[12] Contrary to this, the casing stones which remain on the pyramid of Mycerinus are cut to a rough 52 degree angle—not stepped. It could be argued that this is the result of the workers having been interrupted during the final dressing process, but the roughly angled stones clearly exhibit bosses on their outside surfaces. The only purpose these bosses could have served would be to take the points of levers which the builders used in order to manipulate the stones into position (from the outside of the pyramid).[13] This evidence suggests, contrary to Dunham, that the casing stones, when laid, were roughly cut to angle and not stepped. Without the steps, there is no support system for the spiral ramps. Additionally, as will later be explained, it is not necessary to build any type of ramp in order to erect a pyramid with steplike casing stones. We must therefore eliminate the spiral ramp as a possible building means.

Not yet considered is the possibility of building a hybrid ramp, using some combination of the materials mentioned. Although this may mitigate some of the stated problems, the use of any form of ramp requires that the pyramid be enveloped as it rises. The shortcoming of all ramps is that they provide a means for raising stone to a given height, but do nothing more. Evidence shows that the casing stone, at least, was put in place from the outside. No ramp theories to date have adequately explained how this might have been done on all four faces without completely encasing the pyramid.

There is no question as to the usefulness of construction ramps at certain times; indeed, there is both written and physical evidence of this. For a building project that does not require complicated measurement, or for one in which the height of the edifice is within the bounds of a ramp, it would be an excellent building aid and, in fact, probably was used in some portions of pyramid construction. There are, however, situations, as previously mentioned, in which the ramp is either unworkable, a greater undertaking than the edifice itself, or interferes with the accurate measurements that are required. In addition, while there is much evidence of causeways for pyramids, the remains of the supposed

[10] D. Dunham, "Building an Egyptian Pyramid," *Archaeology* 9 (1956).

[11] Ibid., 163–65.

[12] Ibid., 165.

[13] Engelbach, op. cit., 86–89.

construction ramps are lacking. For example, the stepped pyramid of Zawiyet-el-Aryan, although it had reached a considerable height, was unfinished. Still, there is no evidence of a ramp.[14]

Having questioned both of the presently accepted ramp theories, we are still left with the fact that the pyramids were built, and done supposedly with a very simple form of technology. It is clear that new avenues of thought should be explored.

As a first step in that exploration, we should investigate whether it is possible to build an accurate pyramidal structure, without the use of a construction ramp. The Egyptians were able to achieve high degrees of accuracy in major building projects with only primitive tools. There is evidence that one of the methods used to accomplish this was building in stages; making each successive stage more exact than the last. The pavement surrounding the pyramid of Cheops was built in this manner,[15] and it seems as if the pyramids themselves were erected by the same method.[16] Perhaps here, it should be mentioned that we must begin with the assumption that all of the true pyramids, although they might contain variations, were probably built using similar, if not identical, technologies. First, there was a central, stepped core of seventy-five degrees, as evidenced by the remains of Meidum. Next, the core was brought closer to the pyramidal shape by filling it out with stepped backing stones. This is clearly shown by the remains of the three pyramids at Gizeh. Finally, the structure was completed by the addition of a smooth mantle which consisted of a single layer of angled casing stone, portions of which remain on the bottom of the Gizeh Pyramids. This method might also help to explain the curious finding on the northern pyramid at Dahshur: two dates inscribed in red ink on the casing-blocks. The first, at the northeast corner, indicates the twenty-first year of the reign of Seneferu. The second, halfway up the face of the pyramid, bears a date of the following year.[17] It is highly improbable that the pyramid could have reached half its height in that time; especially considering that the bottom half contains approximately 87.5 percent of the volume of the stone. It might be possible, however, to have laid only the final casing during that time, for it is only a mantle of stone.

While it is not difficult to understand the method of erecting the first two stages of a pyramid, it is exceedingly more complicated when dealing with the final building stage of angled casing stone. The primary objective of this paper is to present a method by which this might have been done.

Let us put this aside for the moment and consider an observation that, at first glance, seems to have no connection with the stated problem. Petrie, during his survey, discovered a variance in the thickness of the courses of the Great Pyramid. He says,

> Thicker courses were perhaps intentionally introduced where the area of the course was a multiple of 1/25th of the base area; this system accounts for nearly all the curious examples of a thick course being suddenly brought in, with a series above it gradually diminishing, until another thick course occurs.[18]

A simplified version of the graph is shown in fig. 1.[19]

Engelbach sees no significance in base area and thickness, but feels instead that the periodical decrease must mean that the available stone from a quarry was used up before a new supply was drawn upon.[20] I, too, see no significance between base area and thickness but must also question Engelbach's explanation; for to find it supportable, I would have to accept the unlikely coincidence of twenty-five successive quarries, each having a progressively diminishing total yield of stone.

A much more interesting aspect of Petrie's graph is the relationship of the thickness of the course to the height of the pyramid (fig. 2). It

[14] V. Maragioglio and C. A. Rinaldi, *L'Architettura Della Pirimidi Menfite* II (Torino, 1963) 47.

[15] Maragioglio, *L'Architettura* IV, 98.

[16] Edwards, op. cit., 217–18.

[17] Edwards, op. cit., 230.

[18] W. M. F. Petrie, *The Pyramids and Temples of Gizeh* (London, 1883) 221.

[19] Ibid., pl. VIII.

[20] Engelbach, op. cit., 128–29.

seems that while the thickened courses are not spaced precisely the same distance apart, they do occur with some regularity, with an average distance of about twenty-two feet.

It is a general characteristic of all pyramids that the building blocks diminish in size from bottom to top; indeed, it is a natural thing to do, as it takes a greater effort to raise large stones than small ones.[21] Examination of Petrie's graph from bottom to top, show this generally to be the case; yet, at spaced intervals, thicker blocks are introduced. Even as this is done however, the stones begin to diminish again until the next stage so that the general effect is both an overall and periodic diminution of stone thickness. It would almost seem to suggest that the builder of the pyramid, while forced to introduce the thick courses, immediately went back to the natural manner of laying stone.

For lack of any other reasonable explanation, we must conclude that this pattern was part of the building procedure. In order to ascertain which part, let us begin with a brief description of a method for raising stone, using the stepped inner pyramid itself to support the block as it rises from course to course.

As a block on the ground level is brought to the edge of the first step, it is raised straight up, adjacent to the edge by either rockers or direct levering. When the edge is cleared, the block is pushed horizontally onto the top of the first course. The block is then brought to the edge of the second course and the process repeated. The height of the courses of the pyramid varies from two to four feet. Therefore, each lift will be a small increment of the total height to be achieved.

Petrie suggested that the ancient model of a wooden rocker appliance found at a deposit of Queen Hatshepsut was possibly used as a means for raising stone.[22] In addition, there is an indication that stairways were sometimes used in Egyptian construction. One example of this method is found against the White Wall at the pyramid of Sekhemkhet. While it is certain that the wall was never finished, it was to have been 10.50 meters high.[23] In fact, Engelbach says:

> The finding of the wooden appliances known as rockers in the foundation deposits of the New Kingdom, has been seized on by certain scholars to prove that the method outlined by Herodotus was that actually used. Let it be assumed that there are rockers in unending numbers, strong enough to support blocks up to ten tons in weight, and that the blocks were rocked up step by step and laid. When the top was reached, the appearance of the monument would be very much like that of the Giza pyramid to-day. In the putting on of the facing, two possibilities present themselves; either the top casing-blocks were also rocked up and the lower courses in some mysterious manner slipped in below, which is a mechanical impossibility, or that the appearance of the casing-blocks before they were dressed, was also that of a series of steps—for by no other means could they also be rocked up. This is directly contradicted by the appearance of the unfinished casing-blocks in the Third Pyramid and also by all other known examples of unfinished masonry.[24]

The statement by Engelbach is correct, and clearly at the heart of the problem. While it is possible to raise stone step by step with the use of levers, it is not possible to use angled casing stones as steps.

In addition, it clearly shows that Dunham's spiral ramp is unnecessary because he requires the casing stones to remain step-like, and to be cut back only in the final finishing process. It would surely have been preferable to raise stone over the stepped portion of the pyramid in the manner described above than to go through the effort of building a spiral construction ramp.

The stepped method of raising stone in fig. 3 shows the method of raising a block up a stepped casing stone structure. If however, the corners of the casing stones were cut to angle, they could not be used as steps, for, having raised the block, it cannot be pushed across the intervening space. With the addition of a temporary masonry step however, the missing corner can be replaced and the method would become workable once again

[21] Maragioglio, *L'Architettura* III, 58.
[22] Engelbach, op. cit., fig. 89.
[23] Maragioglio, *L'Architettura* II, 16–17.
[24] Engelbach, op. cit., 121.

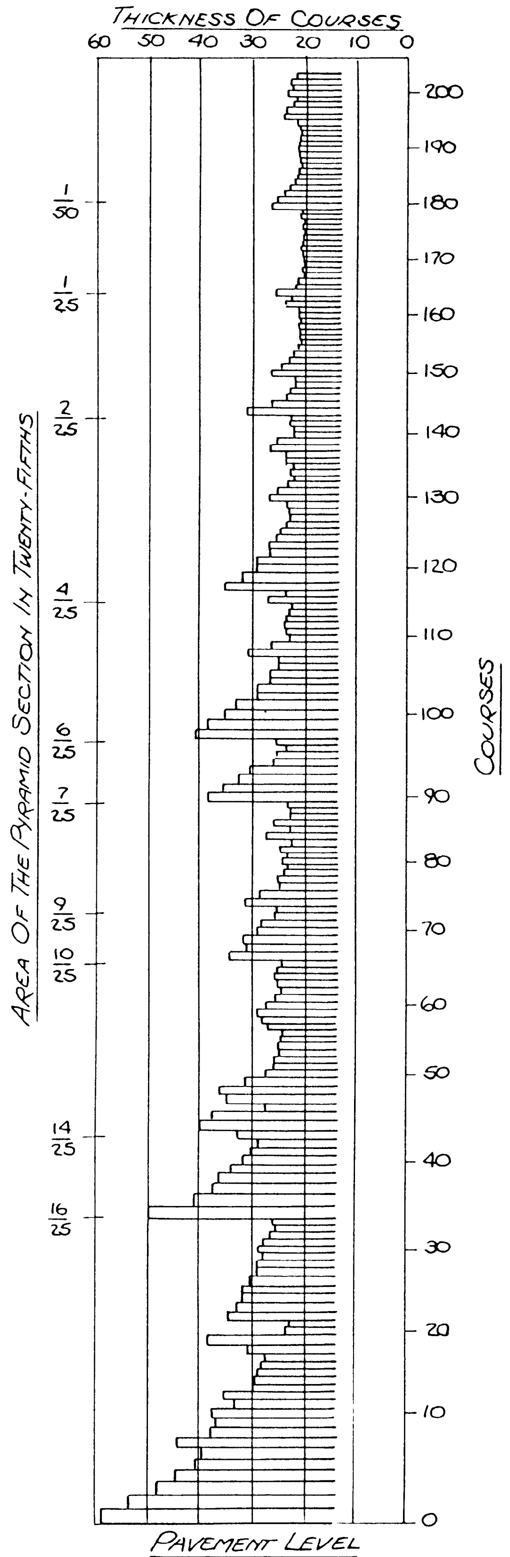

Fig. 1. Incremental course thickness of the Great Pyramid (after Petrie).

(fig. 4). Unfortunately, by continuing to add steps to the angled faces, we would find that, as the temporary addition goes higher, it becomes more unstable. The reason is, even though the structure bears against the fifty-two degree angled face of the pyramid, the two are not interlocked and the shear forces that develop would tend to destablize the temporary step structure as its height increases (fig. 5). This can be overcome by having occasional casing stones project from the angled surface of the pyramid to key them together (fig. 6). These, in turn, can be cut to angle when the faces are dressed from the top, down. The main objection to this method of laying casing stones is that as we add steps to the face of the pyramid, it becomes hidden from view and, if continued, would result in the entire pyramid being encased within four gigantic stairways. This is unacceptable, as it would violate one of our previous objections to the ramp theories.

If however, instead of covering the entire face of the pyramid with steps, we cover only a small centrally located portion of it, wide enough to provide workroom, it would still give us the means for raising the stone. Now, however, when the stone reaches its proper level, it must be distributed horizontally. This is precisely where Petrie's thickened courses come into use. If periodically, instead of laying angled casing stone, the builders place a course of projecting stone, it could serve not only as a staging platform on which to distribute other casing stones, but also act to key the central supply steps to the pyramid. In order for this staging platform to rise to the level of each successive course, the projecting stone platform would remain in place and an embankment, composed of small units of masonry or mud brick with wooden runners on its surface, would be built upon it. The projecting stones would be made thicker to support the additional weight. Along with the embankment rising with each course, the supply steps would rise with the embankment to enable the workers to bring the stone to the uppermost level.

At a point that, in the builder's judgment, it was necessary, they would cease to increase the height of the embankment and a new course of projecting, thickened stone would be put in place. This done, the previously laid embankment, being of no further use, would be transferred,

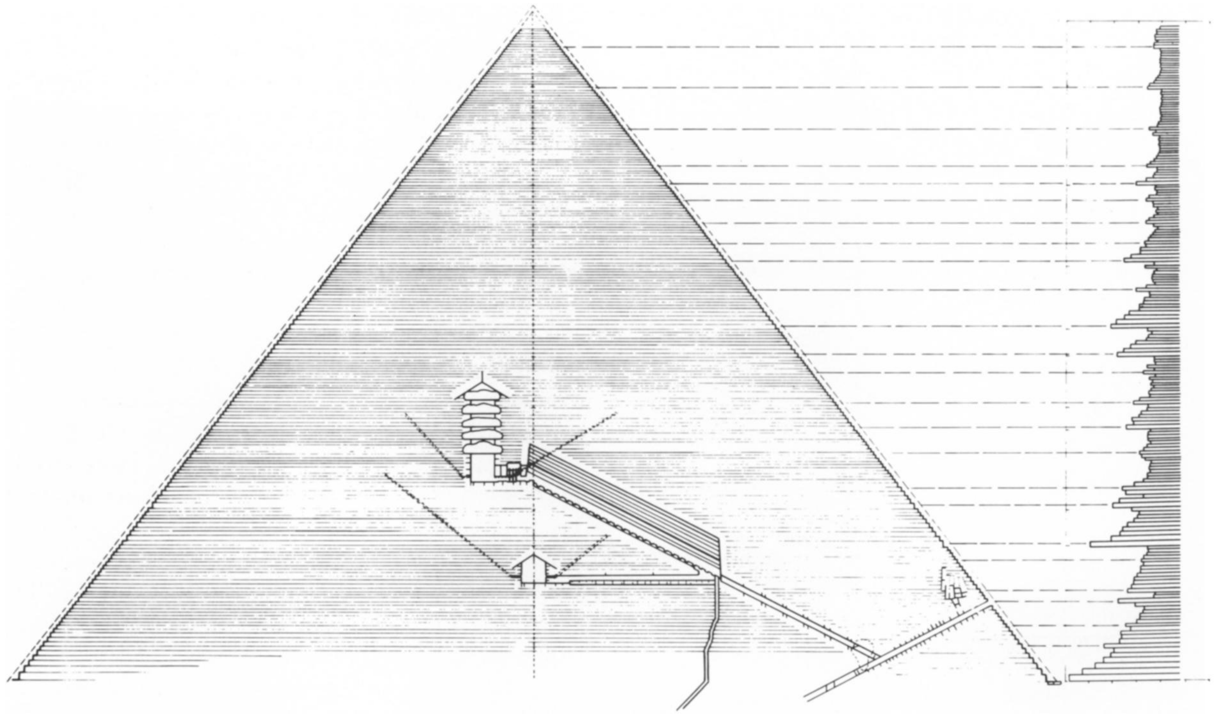

Fig. 2. Relationship of incremental thickness of courses to height of Great Pyramid.

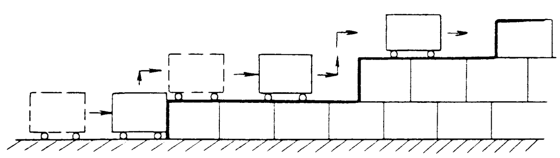

Fig. 3. Method of raising blocks up a step-faced structure.

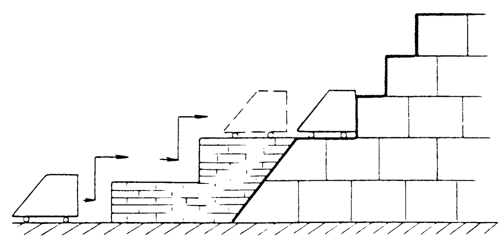

Fig. 4. Method of raising blocks up an angle-faced structure.

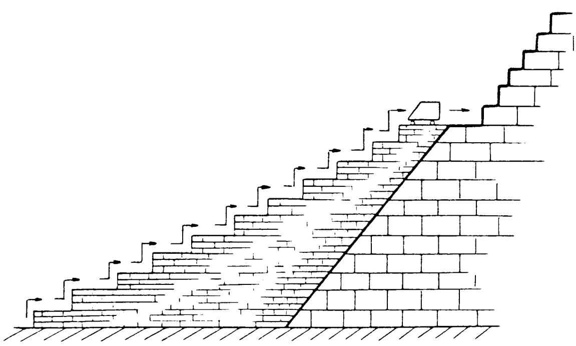

Fig. 5. Unkeyed stepped addition to angle-faced structure.

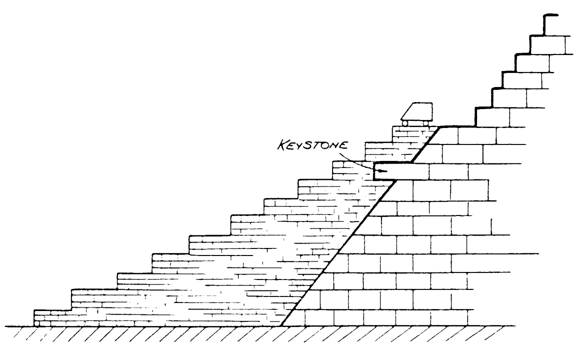

Fig. 6. Keyed stepped addition to angle-faced structure.

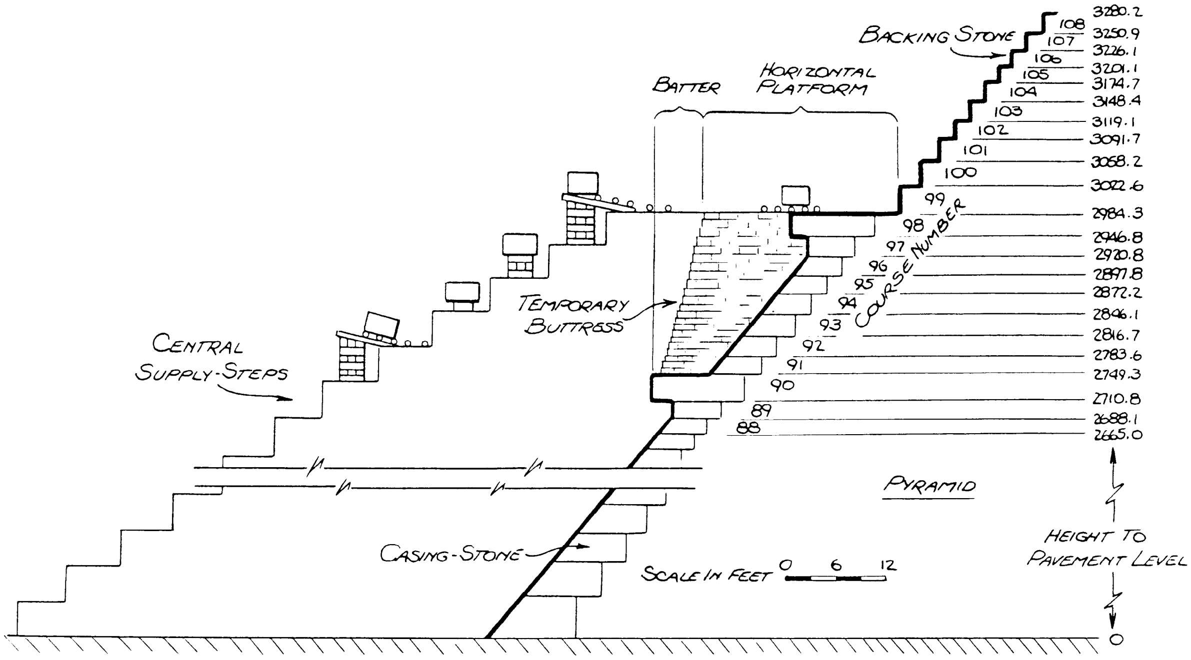

Fig. 7. Sectional view showing size of horizontal work platform at course 98.

as the need arose, to the next higher stage and the process repeated. In summary, the entire pyramid would be built, from bottom to top, with a succession of projecting stages which support embankments that would be moved upwardly, from stage to stage, until the entire project was completed. On completion, the roughened blocks would be dressed and the projecting stone removed from top to bottom. The embankment covers only one stage at a time, and upon its completion, moves to the next higher stage—the pyramid is always exposed. Thus, we are able not only to raise and place the casing stone, but to do so with great accuracy. An interesting feature of using the pyramid itself as the means of raising stone is that, at a fifty-two degree angle, any increase in height gives almost the same increase in depth. This would make a buttress built on the projecting course almost as deep as it is high, and the resultant horizontal workroom would enable small teams of men with levers to manipulate the stone.

There is another feature of interest. Because the pyramid decreases in size as it rises, the size of the staging embankments (which ring the pyramid) also decrease, and therefore require ever diminishing amounts of stone. This excess stone may be transferred to the central supply stairs and thus help speed the building process.

The series of figs. 7–11 shows the sequence of the procedure. The courses from 88 to 108 are to scale, in order to show the amount of workroom that would be available as the buttress increases in height. The central portion of the pyramid has been chosen as an illustration; for, by then, the workers would have solved many of the initial problems that might have occurred and would be in full command of the building process. As shown in fig. 8, the addition of courses 99 and 100 had with it an accompanying addition of a newly started buttress and an increase in the height of the main supply steps. The embankment between courses 90 and 98 has been removed in fig. 9, and is being rebuilt on top of course 98. At course 108 (fig. 10), a level which the builders deemed necessary for the start of another stage, a thickened block is shown being brought into place.

The stages would start anew at whatever point the architect thought that building conditions demanded it. It should be noted that because of

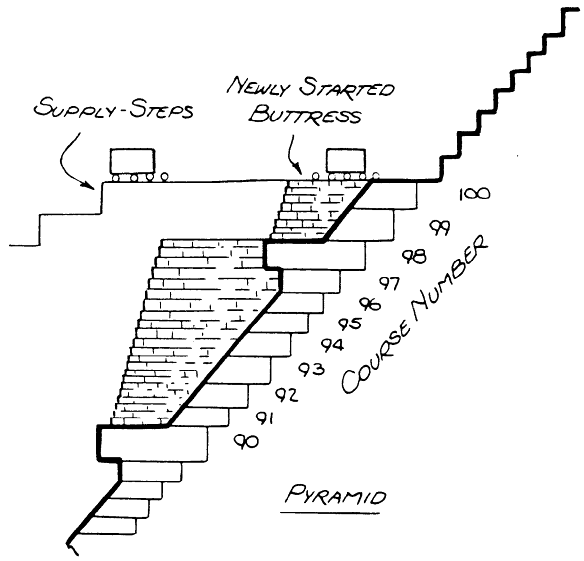

Fig. 8. Size of work platform at course 100.

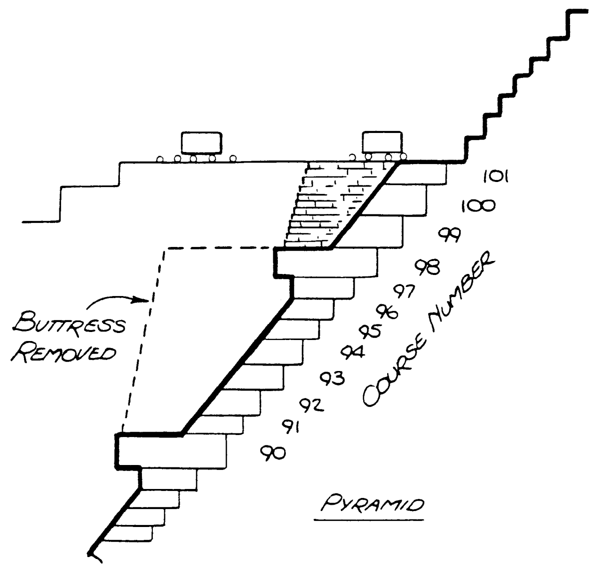

Fig. 9. Size of work platform at course 101.

the angle of the pyramid, much of the embankment weight will be borne, at all times, by the pyramid and not solely by the projecting stone.

Interestingly, in this method of construction, the central supply steps need not be restricted to only one face of the pyramid. Indeed, it would be helpful to have similar stairways on each of the four faces so that they can be worked simultaneously. A plan view of this can be seen in fig. 12, showing the supply directed toward the pyramid from each side. In addition to the obvious advantages in building speed, by giving each face its own stairway, the placing of the casing stones would be simplified in that, having brought the stone to course height, there would be no need to manipulate the blocks around corners. Therefore, each course could be laid from edge to edge with a minimum of effort. In fact, each embankment, by girdling the pyramid, would allow work teams on adjacent faces to assist in laying the corners.

We should now consider, in detail, the means of lifting the two- to three-ton stones from one step to another. The rocker method that Petrie mentions may be used to accomplish this. Fig. 13 is an example of how this is done. The block, supported by the cradle, is tilted from end to end and wedges are slipped in until the desired height is reached. I am, however, more experienced with the direct levering method which evidence indicates the Egyptians used.

Having been a sculptor, there were times when I had to move and lift a block of marble weighing up to three tons, and often to use a primitive means of doing so. I recall occasions when I lifted one thousand pound blocks three feet up by levering each side up alternately and placing a strip of wood under it. As the height of the strips increased, the block rose. It was a surprisingly easy procedure, with one man doing the levering and another putting in the wooden blocking. As the weight of the block increases, it would become more difficult to do. In that case, instead of one man per lever, there may be two. There may also be two levers per side to further increase the lifting power. Having done this lift with ease, I have no doubt that an experienced team of men can accomplish much more. The basic process of the levering means is shown in figs. 14–15. It should be mentioned that the fulcrum must also rise with the block for maximum leveraging efficiency.

The lift shown has only a vertical component; there must also be a horizontal one. To transfer the block, two wooden beams extend from under it to the next step (fig. 16). The block is lifted to

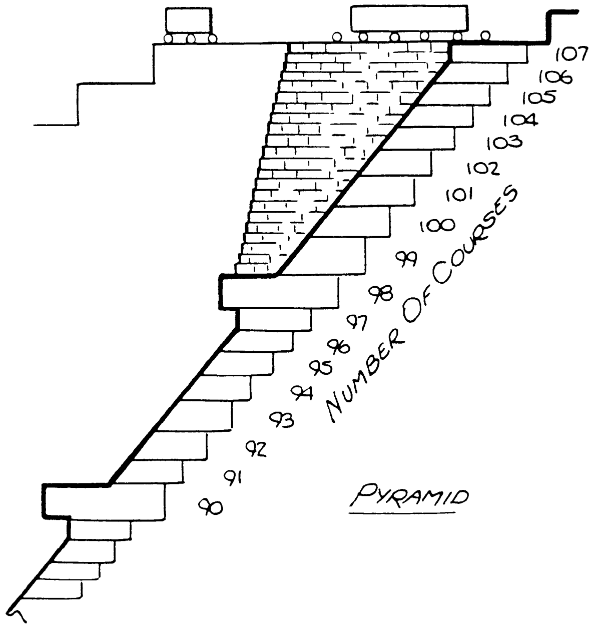

Fig. 10. Size of work platform at course 107.

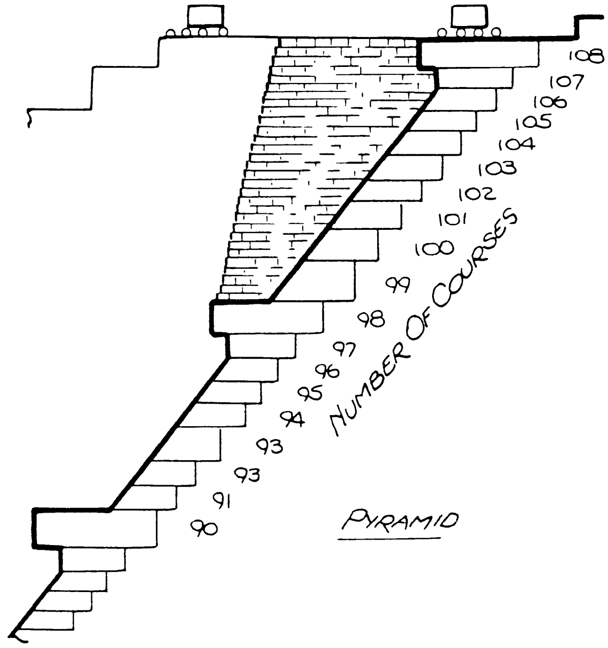

Fig. 11. Size of work platform at course 108.

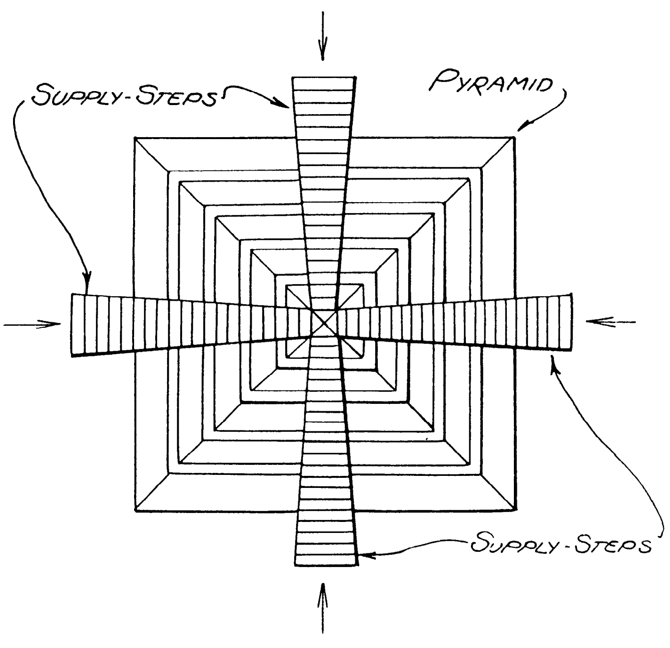

Fig. 12. Diagrammatic plan view of pyramid showing supply steps on each face.

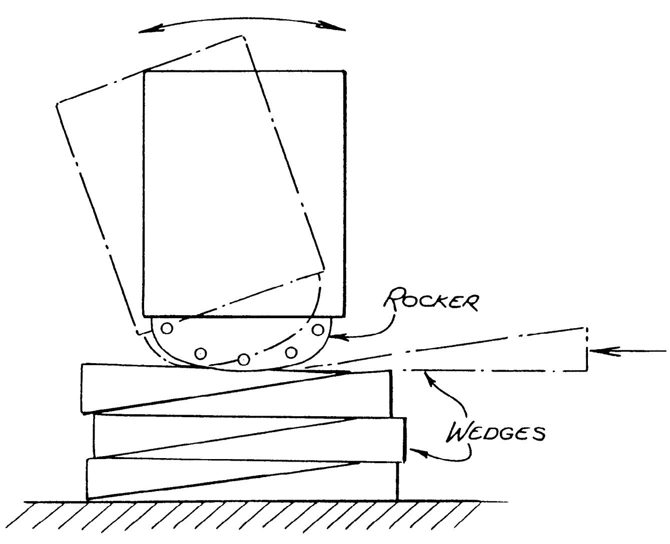

Fig. 13. Petrie rocker method of raising stone.

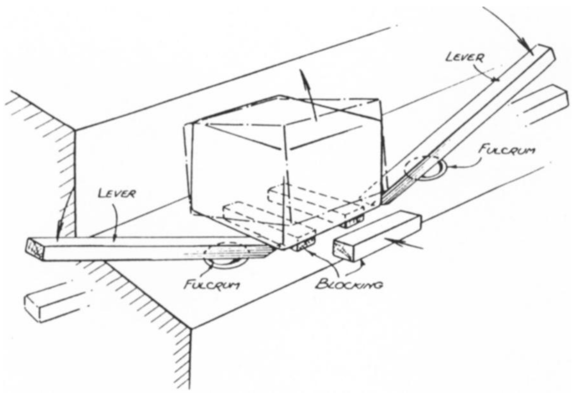

Fig. 14. Lever and block method of raising stone.

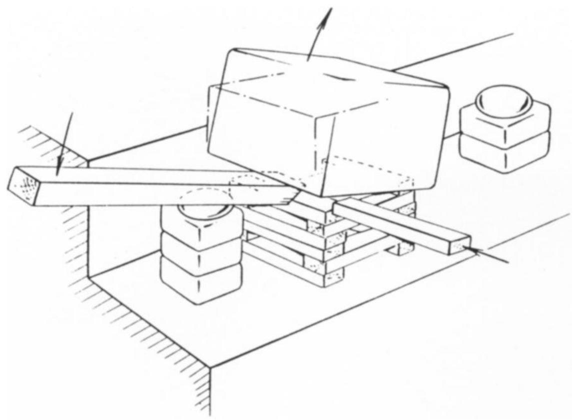

Fig. 15. Method of raising fulcrum as block rises.

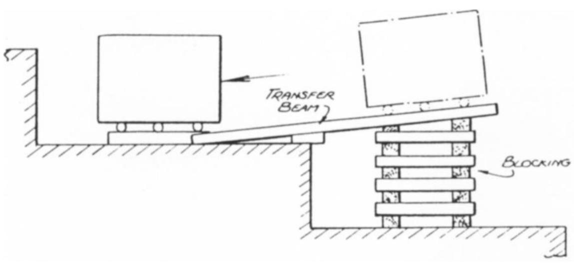

Fig. 16. Method of transferring block from one step to another.

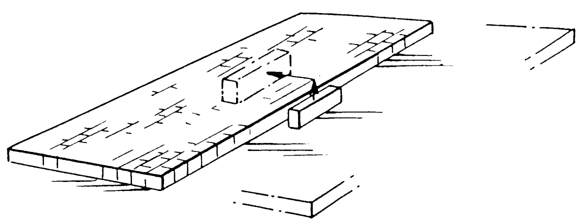

Fig. 17. Raising fifty-ton chamber block up first course.

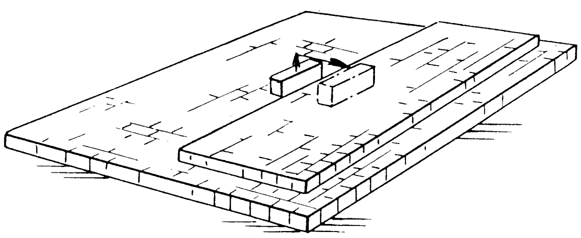

Fig. 18. Raising fifty-ton chamber block up second course.

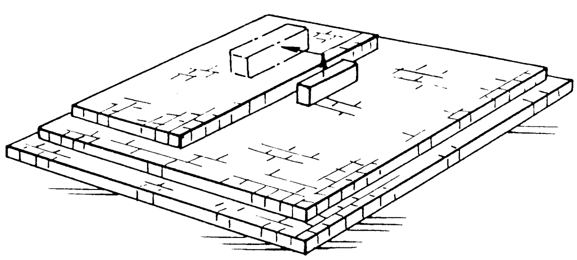

Fig. 19. Raising fifty-ton chamber block up third course.

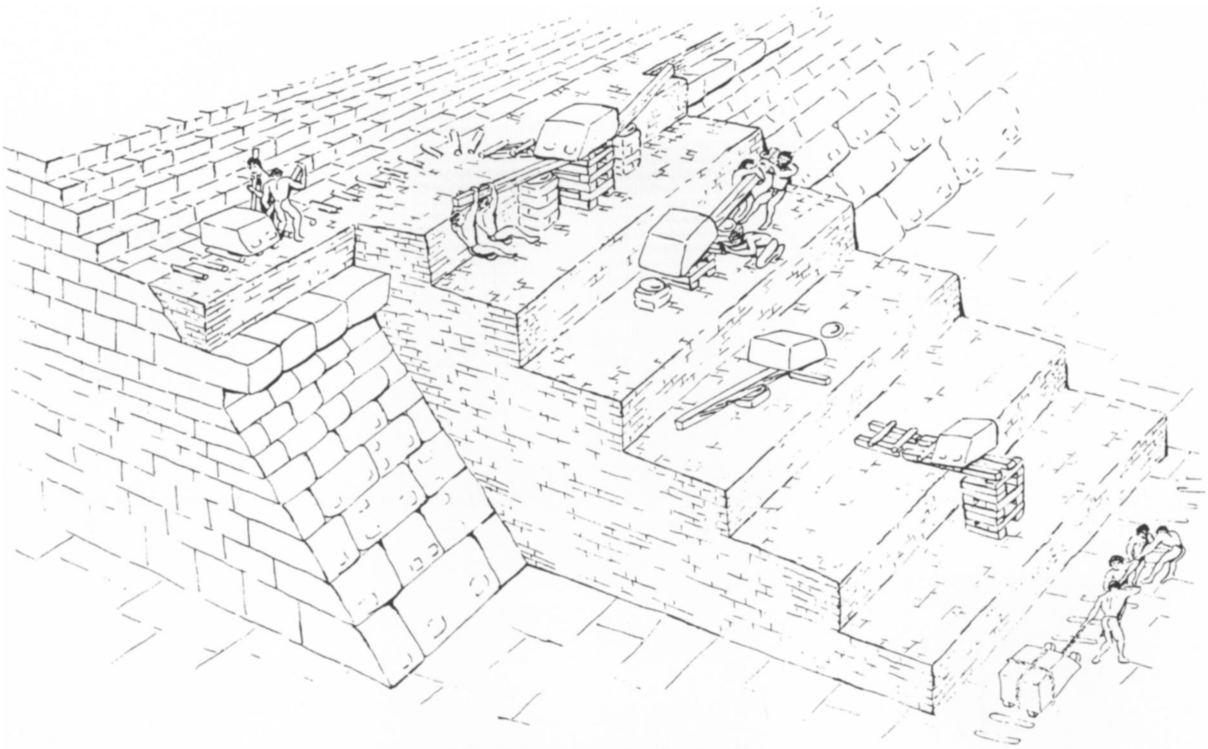

Fig. 20. Pictorial view of proposed method of raising casing stone.

permit rollers to be placed underneath and is then rolled to the next higher step. The procedure is repeated step by step until the proper course is reached. The block is then rolled to its proper position and placed therein.

While we have been previously discussing a method of laying the mantle, made up of two- to three-ton blocks, over the inner stepped pyramid, let me now propose a method of raising and placing in position the fifty-ton chamber blocks. It is believed that the passages and chambers were planned before the erection of the pyramid.[25] If so, it would be possible for the monoliths to be placed in position during the first building stage, and worked before being covered. Indeed, there is evidence that this is the case.[26] The procedure might be as follows. When a portion of the first course is in place, the monolith is brought to its edge, levered up, and transferred on to the top (fig. 17). The first course is then completed plus a portion of the second course. The block is once again lifted, transferred (fig. 18), and the second course completed along with a portion of the third (fig. 19). The procedure would be repeated until the required height for the block is reached. The monolith would then be placed and dressed, and the rest of the course would continue to rise around it, along with other monoliths destined for higher placement. The chamber blocks possess signs of the same bosses that their smaller companions had, and therefore could have been manipulated by using a levering system. To lift these blocks would require more men and levers but, being larger, they present more surface area on which to apply the levers. The chamber blocks may also have been transferred from course to course by means of ramps. The courses are only three to four feet high, and the ramps required would be of a small size.

In review, I have shown a pictorial detail of the lifting means described in the paper (fig. 20);

[25] Petrie, *Pyramids and Temples,* 165–66.

[26] Maragioglio, *L'Architettura* IV., 126.

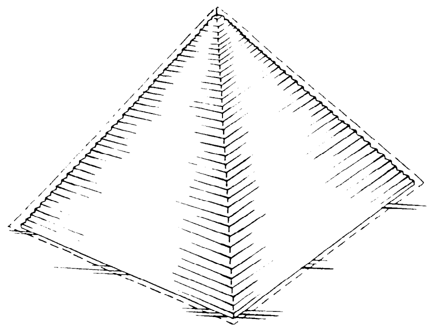

Fig. 21. The pyramid with packing stone.

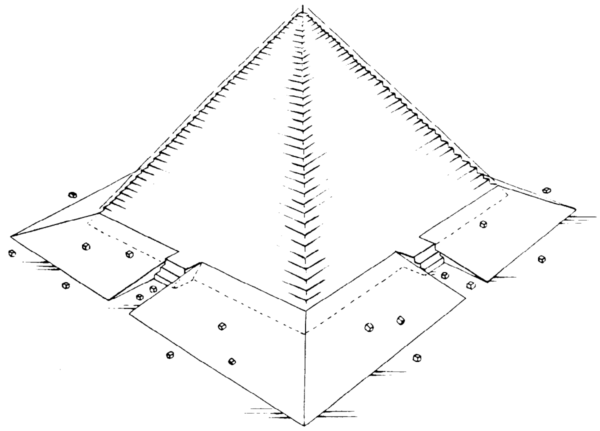

Fig. 22. Pyramid with lower courses of casing stone being applied with the aid of steps and ramps.

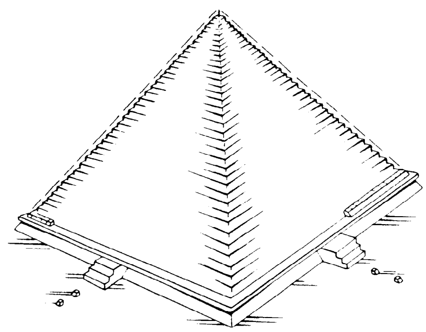

Fig. 23. Ramps removed when first projecting course stage is reached.

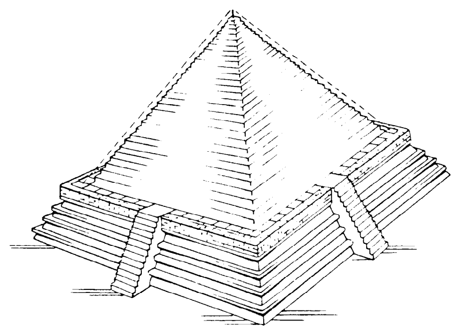

Fig. 24. Pyramid several projecting courses higher.

also, a series of overall drawings on the general procedure (figs. 21–28). Before the first projecting course has been placed, a means must be found to lift the casing stones and move them horizontally along the courses. Because it is the stage closest to the ground, there are a number of ways this can be done. Banks of steps can leapfrog each other until the courses are filled; low ramps may be built to the first stage; or, as I have illustrated in fig. 22, a combination of ramps with the central stairway can be used. Once the first projecting stage is placed, everything but the one central stairway can be eliminated, for this is all that is necessary (fig. 20). As shown in figs. 24–25, the stages and stairways continue to the top until they converge (fig. 26) to a large platform area for the capstone. The pyramid is shown being dressed from the top, down in fig. 27 and finally completed in fig. 28.

In addition, I have shown (fig. 1) that although there are occasional courses that are, apparently without reason, either thicker or thinner than their companions, in general the stones diminish in size, not only from bottom to top, but also in periodically repeated stages. This was deliberately done and indicates to me a method of building pyramids which seems to solve many of the perplexing problems that previously existed.

Having described my proposed building method, it might be worthwhile to close by citing the method described to Herodotus when he visited Egypt over two thousand years ago; keeping in mind that the pyramids then were as ancient to him as he is to us:

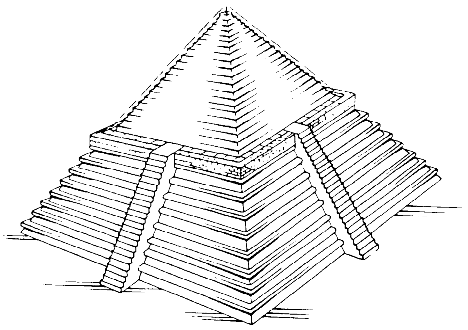

Fig. 25. Pyramid as it would appear above the halfway point with its casing stone in place.

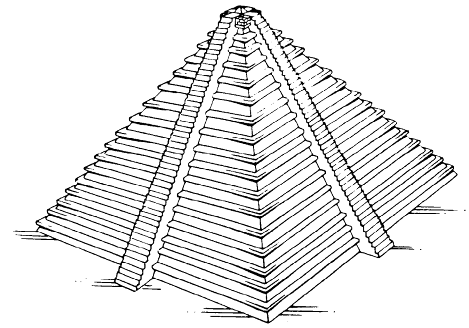

Fig. 26. Pyramid showing workspace available on the apex for placement of the pyramidion.

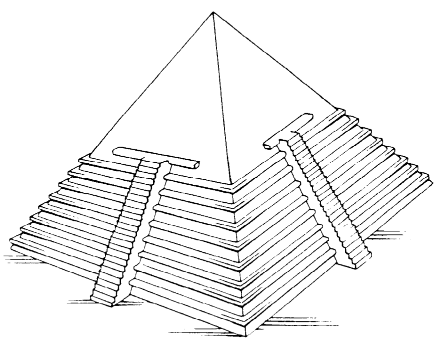

Fig. 27. Pyramid with all its casing stone placed, being dressed from the top down.

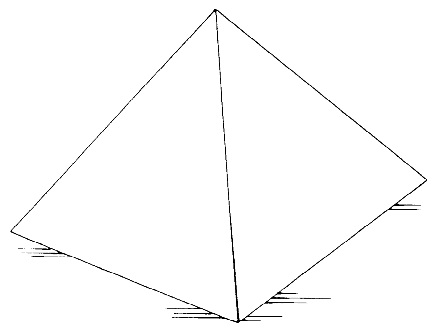

Fig. 28. The Great Pyramid completed.

The ascent was regularly graduated by what some call . . . steps and others . . . altars. When the workmen had finished the first tier, they elevated the stone to the second by the aid of machines constructed of short pieces of wood; from the second tier the stones were raised by a similar machine to the third; and so on to the summit. Thus, there were as many machines as there were courses in the structure of the pyramid; though there might have been only one machine, which, being easily manageable, could be raised from one layer to the next in succession.[27]

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[27] *Herodotus*, II, 125, in Wheeler, op. cit., 394.