The Bent Pyramid

The curious case of the 60 degree pyramid.

Keith Hamilton 1st June 2017

This paper is a by-product of the research I have been doing on the Bent pyramid, which will culminate in my layman's guide to said structure. In the course of my research, I began to feel uneasy at the narrative that has largely taken hold of the structure; a narrative that invokes a 60 degree pyramid, subsidence that brought about changes in plans and faulty pyramid foundations. It was a narrative that I could not recognise; then by chance, I came across a PBS production called *Time Scanners* and an episode that they did on the Egyptian pyramids.

In part of this episode, they used laser scanning technology to scan the interior and exterior of the Bent pyramid. Leading the team was one of the world's finest structural engineers, Steve Burrows. In conclusion of his research on the Bent Pyramid, Steve was happy to admit that his preconceptions had been wrong and that *"by structural analysis this was designed like this. It hasn't failed; this is actually a great success"*

Here was a statement, which my own research seemed to mirror. This paper therefore is to revisit the evidence that has led to the standard narrative/model and provide a possible alternative that is closer to Steve Burrows statement.

The standard narrative is best summed up from the following quotes;

Corinna Rossi, in her book, ***"The Pyramids and the Sphinx"*** says;

"During the construction of this first pyramid a series of difficulties was encountered that resulted in the so-called Bent Pyramid, so called because its lower-section slope is steeper than its upper- section slope. This decided change in inclination, however, was not the first problem the architects were obliged to tackle during construction. The careful exploration the Italian experts Vito Maragioglio and Celeste Rinaldi made of the underground

corridors showed that the Bent Pyramid has another pyramid, smaller but steeper, inside it.

When the original pyramid had reached a considerable height, an internal section of the construction subsided, perhaps due to the lack of resistance provided by the desert beneath.

The architects understood that the structure would not be upright and so built a wider, less steep pyramid around it. Unfortunately further structural subsidence occurred and the architects finally decided to reduce drastically the slope of the pyramid's faces and therefore complete the upper structure using a smaller quantity of stone that had been planned."

Zahi Hawass, in his book ***"The Treasures of the Pyramids"*** says;

"The ensuing alterations necessitated by subsidence and damage during construction resulted in a chamber system in this pyramid that is extraordinarily complicated and difficult to follow. ----------

In order to facilitate the excavation of a shaft of about 7x7m and 22.5m deep, an underground layer constituted of mixed layers of marl and slate as at Saqqara was chosen, this was not, however, adequate to support the weight of the stone masses. As the pyramid grew upwards; sizeable cracks appeared in the three chambers and in the corridor; initially it was thought sufficient to repair these by fillings. However, soon it became evident that both the lower chambers and the entrance corridor were seriously damaged and could not be saved by any further reparations.

Eventually all attempts to save the project-even giving up the lower chamber and reducing the pyramids angle of slope-proved to be in vain. After fifteen years of construction work, the boldest of all pyramid projects had to be abandoned."

Miroslav Verner, in his book**; *"The Pyramids, Their Archaeology and History"*** *has* this to say;

"The Foundation on which the pyramid was built consisted not of rock but rather of a relatively soft layer of slaty clay. The builders apparently did not take this sufficiently into account, and this seriously compromised the stability of the whole structure. The core, made of local limestone, rests directly on the clay, whereas the casing of fine white limestone, which is here better preserved than on any other Egyptian pyramid, stands on an artificially built foundation.

According to the original plan, the walls were to have a relatively steep angle of sixty degrees; during construction, the angle was altered to not quite fifty-five degrees, and this required that the base be enlarged. This change from the first to the second stage of construction can be seen in the ceiling and the side walls of the north access corridor to the pyramid, about twelve meters from the entrance.

When the structure was about forty-five meters high, the angle of inclination was further reduced to only forty-five degrees. This modification, which had the effect of reducing the volume of material required for the upper half of the pyramid, was probably made necessary by the danger that some of the internal chambers would be damaged. Thus the pyramid assumed its characteristic form."

To Verner's credit he goes on to say;

In the interests of a complete presentation, we must add that, according to some scholars, the pyramid's unusual shape was not the result of experiments and risks related to static equilibrium, but rather reflects the original structural intention, which was motivated religiously or politically."

Mark Lehner, in his book; ***"The Complete Pyramids"*** says;

"There is evidence within the core of the Bent Pyramid that it began as a far smaller pyramid with a slope of about 60°. But structural problems with subsidence soon set in. Emergency measures took the form of an added girdle around the stump of the pyramid, forming a slope of just under 55°.

These early stages were constructed using the traditional method of laying the courses with the stones sloping inward. Even at the reduced angle it appears that there were still major problems until about half way up, the builders began to set the courses horizontally. It had become clear that the inward-leaning courses, far from aiding stability, actually increased the stresses on the pyramid.

The Bent Pyramid was then continued at a much decreased slope of around 43° to 44°, giving it a pronounced bend. It may have been at this point, before the upper part was finished, that the decision was taken to begin a new pyramid at North Dahshur. Around the same time, perhaps the 30th year of Sneferu's reign according to Stadelmann, work also began on the satellite pyramid."

In a paper by Frank Monnier and Alexander Puchkov ***"The Construction Phases of the Bent Pyramid at Dahshur"*** They say;

"The change in the slope of this pyramid just below the half way point between its summit when complete allows a priori two possible interpretations: it was designed in a completely novel way from the outset, or a modification of the pyramidal shape was improvised during the building work.

The hypothesis that this profile could symbolize an expression of duality is credited to Alexandre Varille who found in the person of John A.Legon his most fervent follower.

This theory would be convincing-indeed, Sneferu built two pyramids at Dahshur, the Bent pyramid has two entrances and two internal layouts-if evidence of structural collapse and modifications had not been found inside the building. This theory is also contradicted by the fact that the burial chamber of the lower layout was never built (cf.supra)

We will not fuel the debate more by commenting further on this matter; we consider that the architects Vito Maragioglio and Celeste Rinaldi collected enough evidence to demonstrate that the unplanned structural issues were significant. The Bent pyramid was enlarged and it led to unexpected consequences, that is to say cracks and subsidence that forced the architects to give this very non-typical shape to the building.

The Italian architects have therefore made an important breakthrough in the understanding of the history of this monument, but their scenario remains an outline. The full reconstruction of the different building phases is still in need of elaboration.

There is little agreement about the precise dimensions of the initial project, or about how to correlate or explain the peripheral joints and the cracks which are located not far from the northern and western entrances. The cracks are not all in close proximity to theses joints, so we have to analyze the structural situation."

The quotes above are basically the consensus opinion on the Bent Pyramid, here there is little ambiguity; it all comes across as a settled matter.

A few scholars, like Varille and Legon have come forward with interesting articles; and more recently Massimiliano Nuzzolo produced a paper *A project failure or an intentional architectural framework?* In his conclusion he states *"Rather it suggests that it was planned and realized with its strange architectural shape from the very beginning,"*

Such scholars are clearly in the minority and face an uphill battle against the standard model, which holds the consensus high ground.

The First Signs of Trouble?

The seeds for the standard model seem to appear in 1839, when Perring did a survey of the Bent pyramid; in his work he states:

"The first part of the northern passage, in length 41 feet 2 inches, at present descends at an angle of 28°38′ on account of a settlement; but the original inclination was that of the remainder of the passage 26°10′."

In the same article, the shape of the pyramid is mentioned.

"It is built in two inclinations, so that the lower part has the form of a truncated, and the upper that of a perfect pyramid; which mode of construction, according to Sir J.G.Wilkinson, was probably occasioned by a desire to complete the building more quickly than it was first intended:"

Here, in the earliest days of pyramid exploration, we can see from the above two statements, a brief outline of today's standard model. These first signs of trouble, implied by the earliest explorers have been added to in the 178 intervening years. From the earliest days to the present day, the story is remarkably consistent, i.e. a story of constructional failure, best explains the Bent Pyramid.

In the world of psychology, there is a well known term called, *the illusory truth effect.* This effect can basically be described as: if a story or idea is repeated enough, people will start to believe that it is true. It is now time to investigate this 178 year story, to see if it is based on fact or if it is an illusory truth. Once again I am indebted to ISIDA-PROJECT.ORG for their kind permission to use their images. All other 3D images are created by myself.

The Investigation.

The previous quotes given by the proponents of the standard model can be briefly summarised as follows; an initial project that incorporated a 60 degree pyramid with a base length of 300 cubits. Subsidence due to poor foundations caused this to be abandoned and a new construction was started to build a less steep pyramid closer to 55 degrees, which in turn was abandoned due to the settlement mentioned by Perring. It was then decided to finish the pyramid quickly by creating a small 43 degree pyramid on the failed lower truncated part.

The previous quotes also rely heavily on the work of the architects Vito Maragioglio and Celeste Rinaldi (M&R) and this will be looked at in detail; but first let us look at the foundations of the Bent pyramid.

The Foundations.

The suggestion has been made by the standard model that the Bent pyramid was built on unsuitable foundations. From Verner's quote, he states;

"The Foundation on which the pyramid was built consisted not of rock but rather of a relatively soft layer of slaty clay."

Similar statements have been made by others, but I have been unable to source the origin of these claims; the origin may be linked to the following statement by M&R, who give the following description of the ground around the pyramid.

"The ground is made of compact clay, with flint pebbles, and is covered by a thin layer of sand and flints. Apparently the pyramid nucleus rests directly on the clay, while the backing-stones rest on a foundation platform, which was built around the nucleus and presents an upper surface sloping towards the inside."

What I have found, that might clarify this misconception, is articles that try to link the Bent Pyramid with the so called Black Pyramid; a Middle Kingdom pyramid by Amenenhet III. For example Wikipedia says of the Black pyramid;

"The pyramid was built on clay that was unable to support the weight and began to sink, just as the Bent Pyramid of Sneferu at Dahshur had begun to sink centuries before. The two pyramids are approximately 1.5km apart."

Similar statements I have seen appear to link the nearby problems of the Black pyramid with the Bent pyramid; the thinking seems to be that the foundations of the Black pyramid are mirrored in the Bent Pyramid, due to their close proximity; but such assumptions would be totally wrong.

Though the two structures are close, the foundations they sit on are literally millions of years apart. A geological map of the area show that the Bent and Red pyramids sit on a homogeneous region of Eocene rock (Eocene era approx 56-34 million years ago) and is described as limestone intercalated with shale stone. In contrast, the Black pyramid sits on a much younger Pliocene region (Pliocene era approx 5.3 to 2.6 million years ago), described as sandstone beds and limestone.

On the Black pyramid, Lehner says;

"What went wrong? Amenemhet III's planners founded the pyramid too close to the valley floor where the clay-like bedrock was further weakened by ground water."

Though the two pyramids may be in close proximity, the higher elevated Bent pyramid may as well be on another planet; in short, the foundations are as different as chalk and cheese.

The Old kingdom engineers had to go deep into the desert to find a suitable location for the Bent Pyramid and the quarries to build it. That location was the Eocene rock, the same applied to the Red pyramid, approximately 2km to the north. In close proximity to the Bent pyramid are 4 depressions that are said to be the quarries for the pyramid, and it has been calculated that their volume is about twice the volume of the pyramid. These quarries flank the pyramid along its north and eastern sides; trenches were dug in the eastern quarry approximately 140m from the pyramid. These quarries provided the stone that built the core of the pyramid, and I feel that we can be fairly confident that the core of the pyramid rests on the same Eocene rock and not clay.

The above statement by M&R on the ground can be misleading; their investigations in the 1960's did not have the benefit of modern geological investigations. They themselves admit;

"The inside structure of the pyramid cannot be seen: the good preservation of the casing as well as that of the backing stones, which is almost total, does not allow any direct observation of the nucleus. Therefore we do not know whether the monument has a nucleus formed by concentric layers, as the pyramid at Meydum previously described, or whether the nucleus, stepped or not, has a homogeneous structure."

What we do know, thanks to Wainwright's tunnel at Meidum, is the care the builders took to found the concentric layers of Meidum on the bedrock. The E3 smooth casing phase at Medium was not founded on the rock, but on the desert surface, some 2.5 metres above the Bedrock foundations of the concentric layers. (For further information, please read my paper, The Meidum Pyramid)

We see something similar at the Bent pyramid, were Dorner's plans suggest that the bedrock is located some 2.5 metres below the casing. This casing for the most part are laid on single foundation stone's, except for the corners were the foundation stones are more numerous and appear to rest on the bedrock some 2.5 metres below.

This may seem a strange construction method for the casing, but as Petrie's survey at Meidum and the Time Scanners production show, they are both successful.

Thanks to what we know of the construction of the Meidum pyramid, I feel that it is not unreasonable to suggest that the core of the Bent pyramid is likewise anchored to the bedrock, and with this in mind, we will now examine the inner apartments and see what clues they can provide.

The Inner chambers and Subsidence.

"There is evidence within the core of the Bent Pyramid that it began as a far smaller pyramid with a slope of about 60°. But structural problems with subsidence soon set in"

The above quote from lehner sums up the next part of the standard model that we will look at and see if the evidence supports it. At this point, a brief overview of explorations done at the Bent pyramid is useful. Though it is arguably the best preserved of the giant pyramids, it is paradoxically the least explored. Perring's work marks the beginning of modern exploration of the structure; Petrie, due to delays in work permits, had limited time and sadly the northern passage had become blocked with debris, so he was only able to provide an external survey and some information on the passage that was not blocked. Serious work really only began at the close of the second world war, when Hussein, Efffendi and Varille began explorations, which involved clearing the small blocks out of the lower chambers and a substantial part of the upper chamber. Sadly Hussein died in 1949. Fakhry, who took over the work, says;

"When the time came to take over the work, all his notes during four years of work had completely disappeared, and all my efforts to find them had failed. I had to depend only on the memory of some of his former assistants or workman for information"

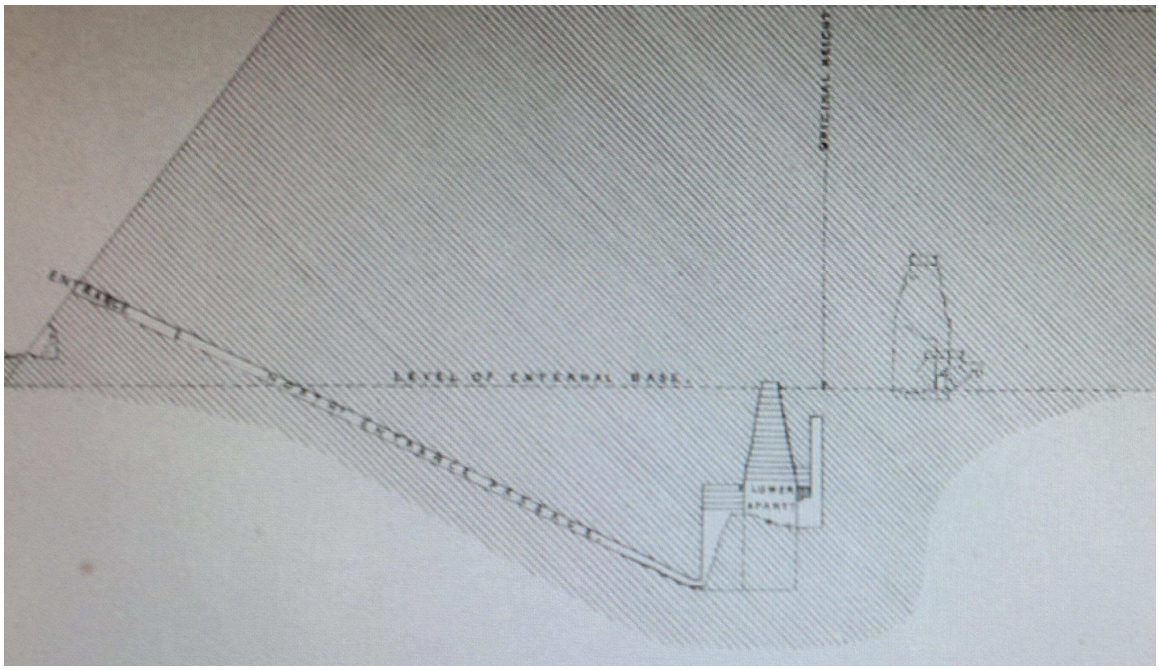
Exploration began again under fakhry in 1951 and his findings were published in a three volume work, The *Monuments of Sneferu at Dahshur.*
The description of the interior is brief and amounts to four pages of text in volume 1; though Fakhry freely admits:

"The interior of this pyramid has been examined but I can never pretend that it has been thoroughly investigated or it does not need more researches in the future"

M&R were next to investigate the pyramid, as part of there multi volume work, *L'Architettura delle Piramidi Menfite (Parte III 1964)* Their work is the more detailed, though even in their time, there were areas they could not observe, such as the pit in the lower chamber, or the floor end of the northern passage, due to debris.

This history of exploration highlights how poor our knowledge of the structure is; for in truth, little has been done since Fakhry's statement, to thoroughly investigate the pyramid. The few black and white pictures in Fakhry's publication are really the only view the outside world had of this magnificent structure. The structure appears to be closed and off limits for some considerable time; with the first colour photographs of the structures interior appearing in 1997 by Andrew Bayuk. In 2012 The ISIDA-Project was granted access and it is their archive of pictures that provides the clearest view of the interior of the Bent Pyramid to date. Their pictures are an important source for any study of the Bent Pyramid.

Let us now look at the lower chambers.



The Northern Passage leading to underground Chambers

The drawing above by Perring shows the northern entrance passage leading to the underground chambers of the Bent Pyramid. The northern passage enters an antechamber, whose width is the same as the passage; so it has a small floor space, but a substantial height, that is terminated by corbelling the top of the east and west walls. The floor of this small chamber is approximately 22.4 metres below the base of the casing according to M&R's drawings. The ancient engineers have excavated a great depth into the rock

and it is possible that the greater portion of the descending passage is trenched in the rock. On the antechamber M&R say;

"The east and west walls of the lower part of the antechamber do not end to the south, against masonry but right against rock: this demonstrates that no vertical stone wall ever closed this part of the room.------The east and west walls are well preserved and with traces of mortar in the part originally covered by the staircase, while the remaining part is quite deteriorated."

This view looking up from the antechamber and the entrance into the lower chamber.

This modern staircase prevents us from seeing the vertical south wall of rock, some 6.75m high. According to M&R's drawings this south wall of the antechamber is in line with the north wall of the lower chamber above. The lower part of the descending passage show similar deteriorating processes that we see at the Meidum Pyramid.

A closer view of a better preserved part of the Antechamber east wall.

The image above is interesting and needs closer scrutiny, are the walls of the antechamber tiled? In my previous work, *The Medium Pyramid,* we see how the builders tiled the walls of the vertical shaft leading to the main chamber. Its use in the Bent Pyramid should therefore come as no great surprise, indeed it would make sense; the Main chamber at Meidum has quite thick tiles that are clearly observable in the south wall breach.

It is quite probable that the corbels of the antechamber are laying on the natural rock and that the walls of the chamber are simply tiled. The advantages of this approach is using the natural strengths of the rock as a foundation, less excavation and a stronger construction; further the end of the descending passage is probably well buttressed against the natural rock. The tiles therefore are not really a structural feature. M&R's view that the south wall never had stone, should be looked at in a new light, for I feel it could have been tiled. Let us now look at the lower chamber.

The lower Chamber.

According to M&R's drawing, the chamber is founded on the rock and paved with slabs inserted between the walls approximately 37cm thick. The rock floor is about 15.3m below the pyramid base.

The image above shows the good condition of the east wall, and the entrance to the chamber in the northeast corner, via the antechamber. And, like parts of the antechamber below, this good condition was preserved by the small blocks that filled a large proportion of this chamber. Perring says;

"It had been filled up with a masonry of small squared stones, to a level with the top of the passage, which had also been in like manner built up."

This close up view of the lower chambers corbelled roof is again in very good condition.

Despite its great age, the corbelled roof is in remarkably good condition, and no evidence of structural failings that I can see.

The strange shape of the chamber entrance.

View along the north wall.

View along east wall towards entrance to chimney.

View along south wall towards chimney entrance, and again are we looking at tiling?

For a more complete picture of the condition of the inner apartments; I thoroughly recommend the reader to visit the ISIDA PROJECT website, were numerous photographs are available. Amongst this archive, are further photographs that suggest tiling has also occurred in this chamber. Like the antechamber below, the corbelled roof of the lower chamber may rest directly on the natural rock, with the chamber walls being mostly tiled, though probably intermingled with larger masonry were it was required, like doorways and the chimney for example. A thorough investigation is required to determine the true make up of this chamber.

This tiling would have no real structural strength, and therefore those superficial cracks that I have observed in some pictures are more probably a result of natural deterioration processes spanning some 4500 years. Certainly there is nothing that I have seen, that I would describe as subsidence; the chambers are remarkably intact and in good condition.

Frank Monnier and Alexander Puchkov in their paper *The Construction Phases of the Bent Pyramid at Dahshur,* state;

"In fact, the lower chamber is in fairly good condition, although it underwent the construction and the clearing of a temporary partial filling. Only one minor crack deforms the west wall of the room. Furthermore, the corbelled vault is in an excellent state of preservation"

The Upper Chamber and Corridor.

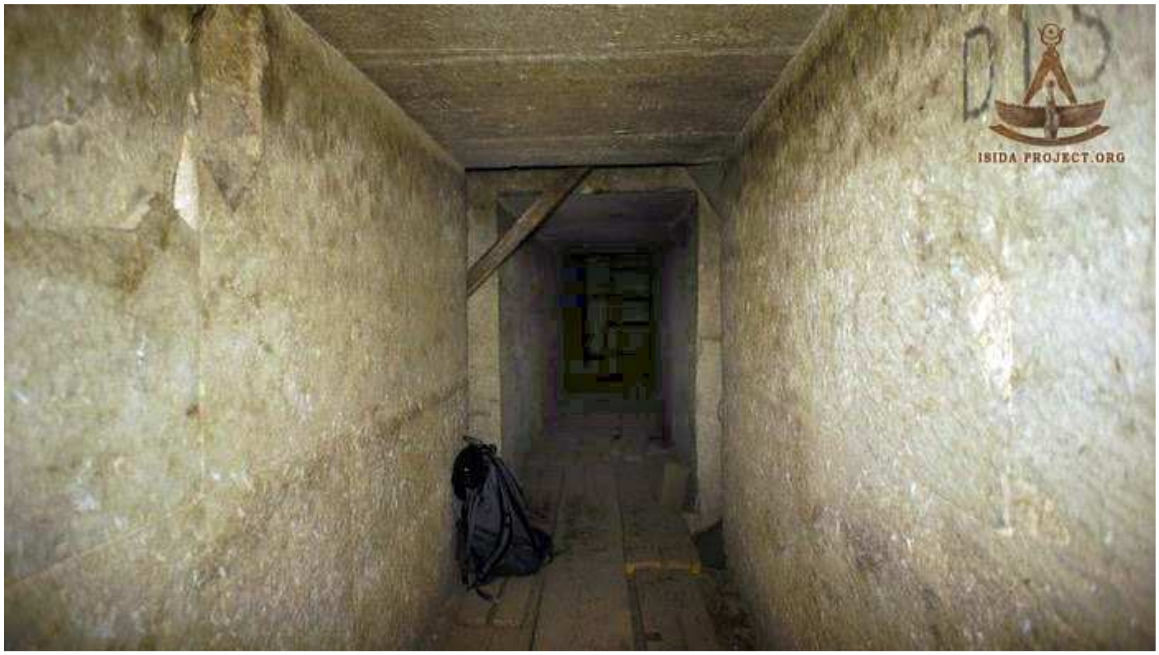
The upper chamber is accessed through a corridor that is aligned to the west, and unlike the lower chamber it is constructed in the superstructure of the pyramid. M&R's drawing shows the chamber floor to be 3.2m above the base of the pyramid. The preservation of the horizontal corridor is excellent and it is very probable that the masonry extends down to the bedrock to provide a good foundation. A clue is in the well built shaft discovered in the horizontal corridor, Fakhry states;

"when the blocks of the floor were removed there was found under them a very carefully built shaft which measures 2.65m by 1.46m and which descended to a depth of 4 metres approximately and was built on the mother rock."

View looking West towards lowered portcullis.

The neat rectangular cut in the portcullis was done in modern times to aid access. The original black and white photograph in Fakhry's work shows a small breach in the top, barely enough for a person to crawl through.

The shaft described by Fakhry.



Looking east toward the upper chamber. The wooden prop is supporting the second portcullis.

The upper chamber has been subjected to wanton destruction and modification, which I will return to in another paper; but for the moment I would direct the reader to the previously mentioned paper by Monnier & Puchkov. For the purposes of this paper we are looking for any signs of subsidence, and the place to look, is the original chamber walls protected by the massif of small stones and wooden beams. The corbelled roof has mostly disappeared; just a faint memory of its past glory can be seen at the very top.

On the upper chamber M&R comment that;

"The walls of the lower part of the chamber where they have been uncovered by the ablation of the massif masonry are very rough, but we were not able to ascertain whether such an aspect was due to rough work or caused by corrosion and stone flaking, The same thing also applies to the overhangs of the corbelled roof of the chamber. ***Even if they do not present any cracks or yielding due to the superimposed weight****, the horizontal edges, which are very sharp and almost intact in the lower chamber, are here damaged to a great extent."*

The highlighted part of the quote above shows how well the roof was constructed; despite the modifications inflicted upon it; it is still structurally sound and no sign of subsidence.

The chamber walls, were visible, are in excellent condition.

Surviving Corbels, hint at the grandeur and quality of work.

Fakhry's published pictures also show the good condition of the chamber floor. Having looked long and hard at the data available to me, I have to conclude that there is no evidence of subsidence or anything for that matter, which may have alarmed the builders. This makes it all the more harder to understand John Romer's narrative on the failings of the Bent Pyramid, described in his Great Pyramid book. Here he describes;

"The pyramid was all at sea, its external building lines and its interior chambers and corridors were moving,--" he goes on to suggest that the situation is best summed up by the vertical chimney, that he suggests was originally in the dead centre of the pyramid, and then states;

"Today, however, after the slow movement of its stonework, the Chimney no longer stands at the centre of the pyramid"

This I feel is clearly impossible, the N-S measure of the Chimney is 1.6metres wide! and connected to the deeply excavated lower chamber.

The 60 degree pyramid.

Having found no evidence of subsidence, the next question to discuss from the standard model, is the 60 degree pyramid. If there is no subsidence, why therefore was the 60 degree pyramid abandoned? The simple answer could be that there is no 60 degree pyramid.

But first a word of caution; surveys have been done by Petrie, Hassan and Dorner and sadly there are issues with them. For example Petrie and Dorner's side length measures for the pyramid are in very close agreement; Dorner's mean being 189.61m. Hassan provides 188.6m a noticeable difference. The structure really needs a modern survey, inside and out. As it is, M&R's drawings rely on a mix of Hassan's work, Perring's angles for the northern passage (Hassan in his survey omits the changes of inclination in the northern passage and simply gives the total length of the passage as 79.53 metres and an angle of 25°24') and their own controls; not exactly satisfactory, but they have done a remarkable job, especially in an age without CAD programs.

From M&R's drawings, I have created an Autocad model to check for errors and test the validity of some of their comments. I have also created a model from Petrie's survey for comparison. Obvious differences appear straightaway. Take for example the differences on perpendicular height;

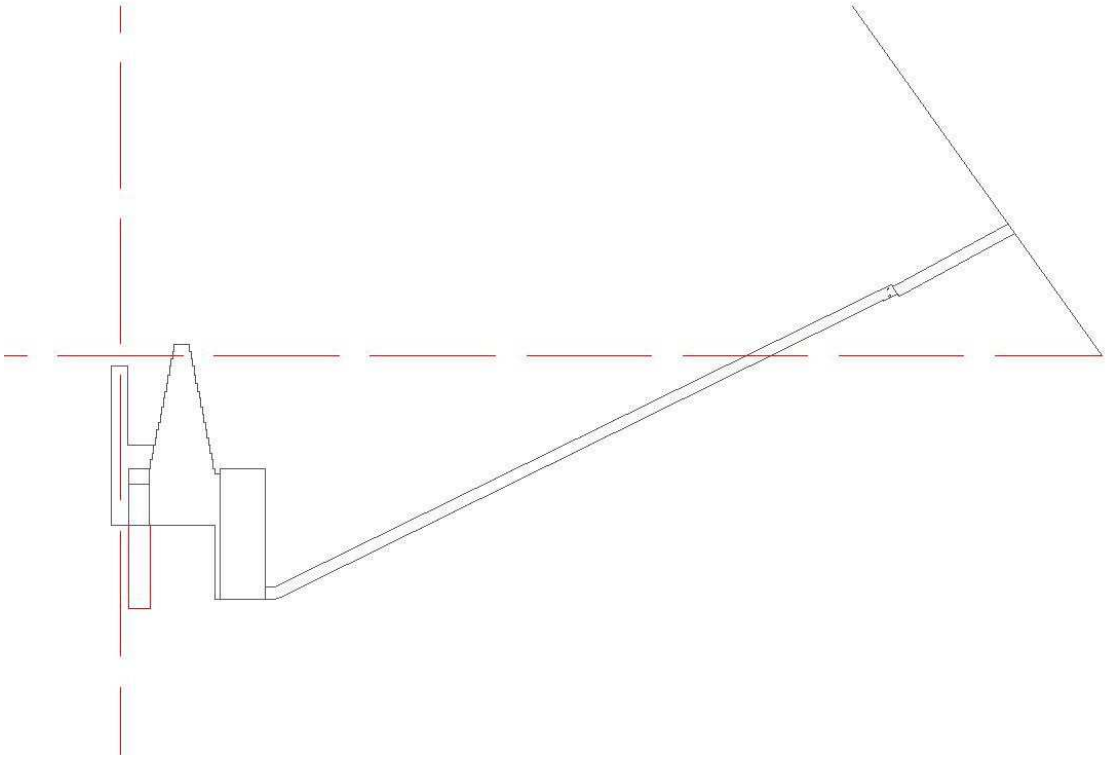
	Lower part	**upper part**	**Total**
Petrie	47.17	57.84	105 metres
Hassan	49.07	52.08 actual	101.15 metres
Hassan		56.00 original	105.07 metres

But by far the strangest error appears to come from M&R; even though Hassan's survey drawings show the chimney directly under the pyramids apex, M&R say;

"Perring states that the chimney is exactly on the vertical axis of the pyramid and both Varille and Hassan Mustafa have confirmed his statement. According to our survey it is slightly shifted to the north of the axis"

The autotcad model I have created from M&R's TAV's 9,10&11, clearly show, that Perring etc are correct; even using Petrie's model, the pyramid axis falls within the chimney, the difference between M&R's and Petrie's model axis is about 60cm. (The Petrie model uses the internals from M&R's model, married to the external dimensions of Petrie)

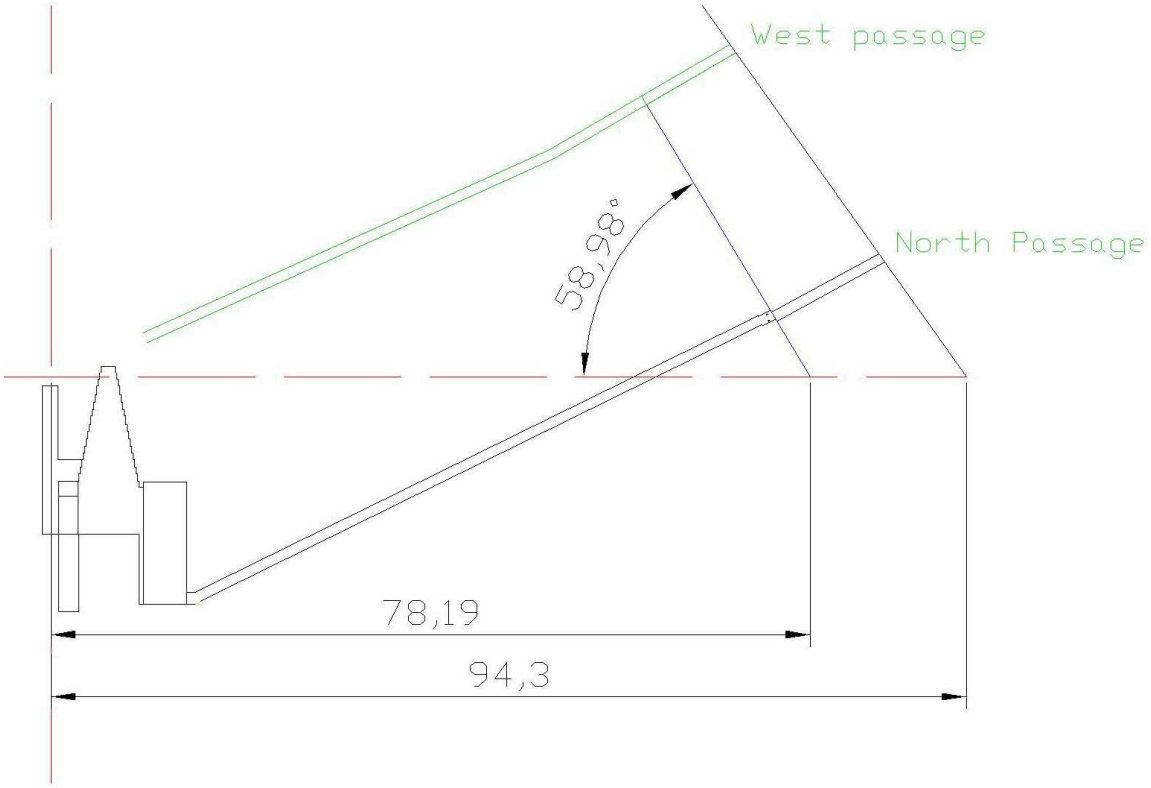
It's hard to understand where they have gone wrong, but due to debris on the passage floor they measured along the ceiling and obtained a ceiling length of 78.6m, they also quote Hassan's corridor length of 79.53m. They may have accidentally used their ceiling length as floor length, this would bring the lower chambers north by just over .6 of a metre; but even this would not be enough to agree with their drawings. In their drawings they do not provide a measure for the chimney shift, north of the pyramid axis; but using a scale ruler they have the south wall of the chimney about 1 metre from the axis. There are other discrepancies and again this demonstrates the need for a modern survey of the structure.



Autocad drawing created using M&R's TAV's 9, 10&11.

The idea for a 60 degree pyramid, comes from M&R. They noticed in both corridors an unusual continuous joint that could be seen running in the floor, ceilings and side walls. In TAV 10, they produced a drawing where they rotated the western passage and aligned it with the plane of the northern passage; and by connecting the two continuous joints, deduced that it formed an angle of 60 degrees and that such a line if extended to the pyramid base, would be a distance of 150 cubits from the pyramid axis. They say;

"We do not think we are distorting facts in making the following hypothesis. Originally the pyramid was planned with a base length of 300 cubits and a face inclination of about 60°--It was namely a pyramid with its vertical median section forming an equilateral triangle. The original entrances of the descending corridors were those determined by the continuous joints which can be noticed in the corridors themselves."



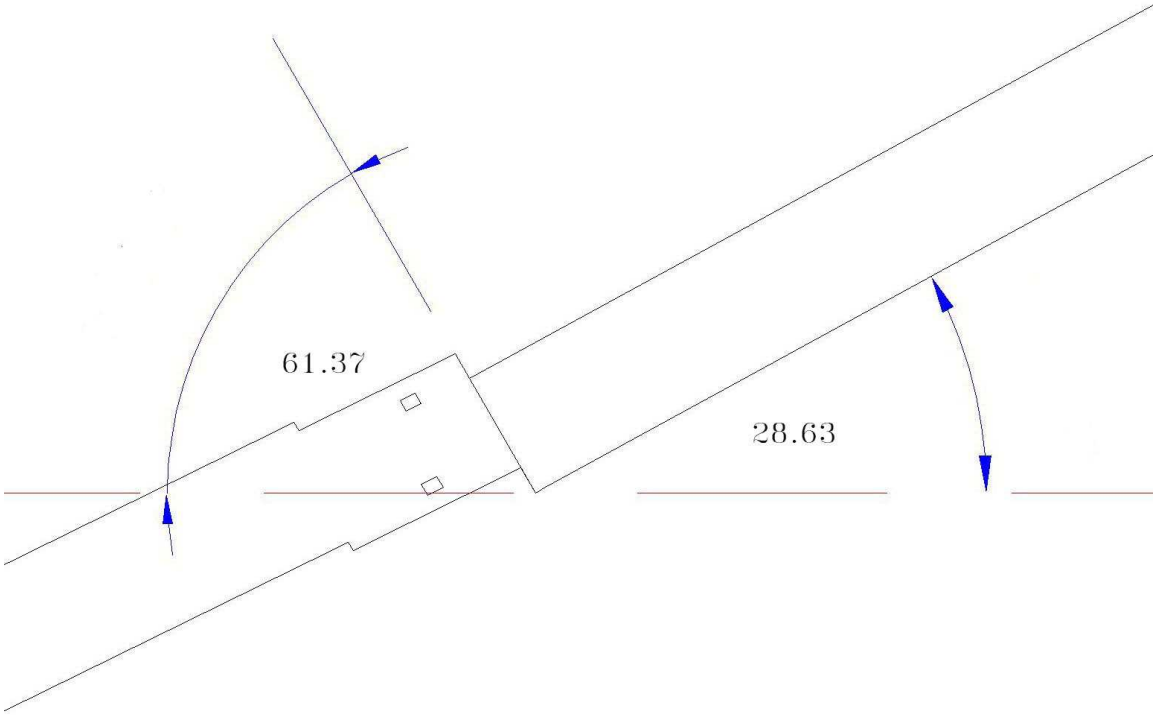
The drawing above is in close agreement with M&R's hypothesis. Hassan's 94.3 metres based on 180 cubits, would provide a cubit of 20.63 inches. The 78.19 metres based on 150 cubits would provide a cubit of 20.52 inches; but given the quality of the surveys, the hypothesis is a fair assumption to make. A similar exercise on Petrie's model gives 78.75m for a cubit of 20.67inches and a steeper angle of 59.51 degrees.

At first glance it seems a closed case but under further scrutiny, some problems began to appear. In 2014 Alexander Puchkov published an informative paper on these joints and passages, entitled *Bent Pyramid Complex. New Observations"* or so the translation software says, as it's only available in Russian. In this paper Puchkov gives the angle of the northern passage continuous joint as 60.5 degrees, however the western passage continuous joints are measured as north wall 55.5 degrees and south wall 58.5 degrees.

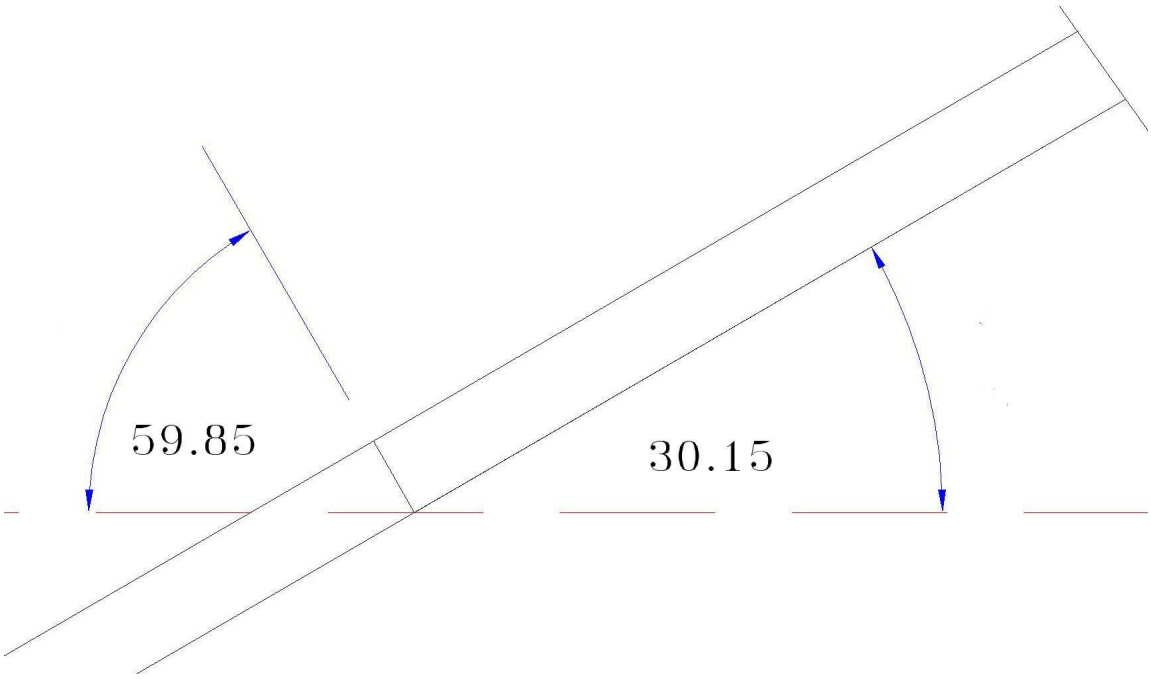
View of the continuous joint in the western passage measuring 55.5 degrees, north wall.

View of the continuous joint in the western passage measuring 58.5 degrees, South wall. Note also the square hole in the wall.

These discrepancies in the angles seem strange, but not if we remove ourselves from the preconception of the 60 degree pyramid. In short, I suggest that what we are seeing are joints that have been made perpendicular to the slope of the passage; the following drawings should make this clear.



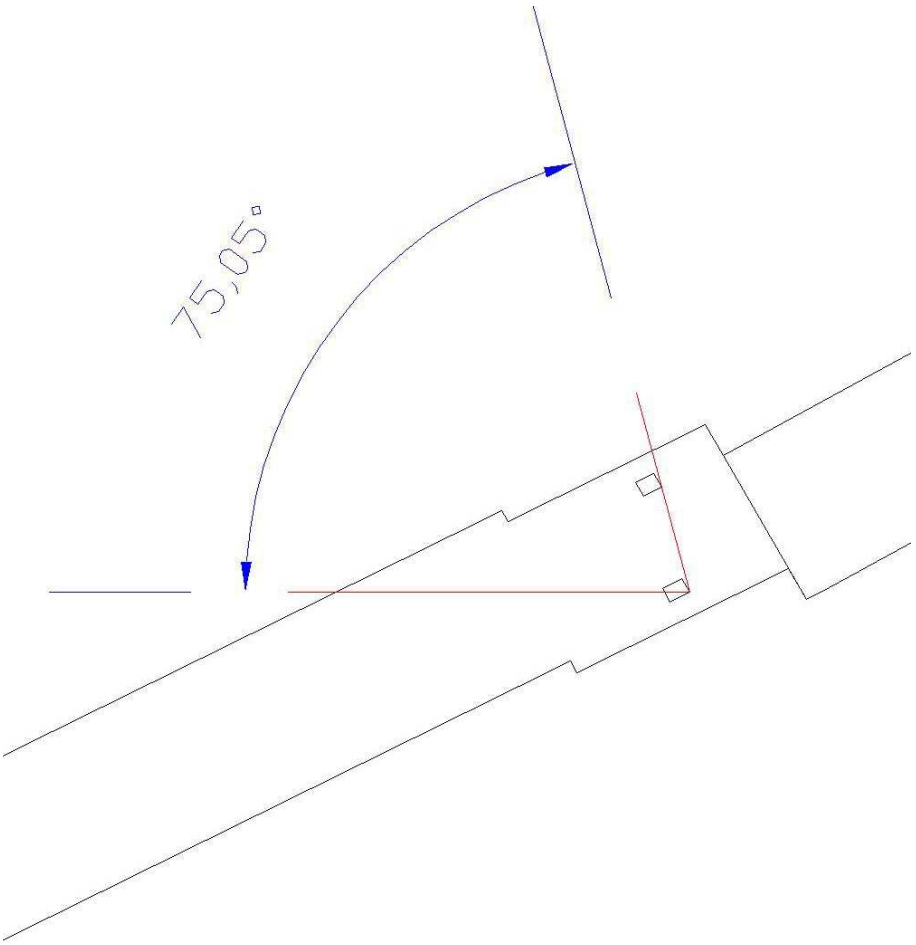
In the image above using Perring's angle for the upper part of the northern passage, which he gives as 28°38′ (drawing above is in decimal) we see that a perpendicular joint laid to the slope of the passage, agrees closely to what has been measured. It's a simple rule of geometry that as the slope of the passage increases, the corresponding perpendicular angle will decrease. Let us now have a look at the continuous joint angles in the western passage.



The upper part of the west passage was measured by Hassan as 30° 9′ (Drawing above is decimal) On the ISIDA-Project website, there is a pdf, that cannot be downloaded, entitled *Bent Pyramid Complex, Facts, ideas, hypotheses*; in this earlier paper by Puchkov we see the earlier measure of the northern joint, by a hand held meter, showing 60.6 degrees on the west wall. Obviously the larger straight edge, used in the western passage would be more accurate, and it would be beneficial to re-measure the northern joint and the joint on the east wall, as no measure has been given for it.

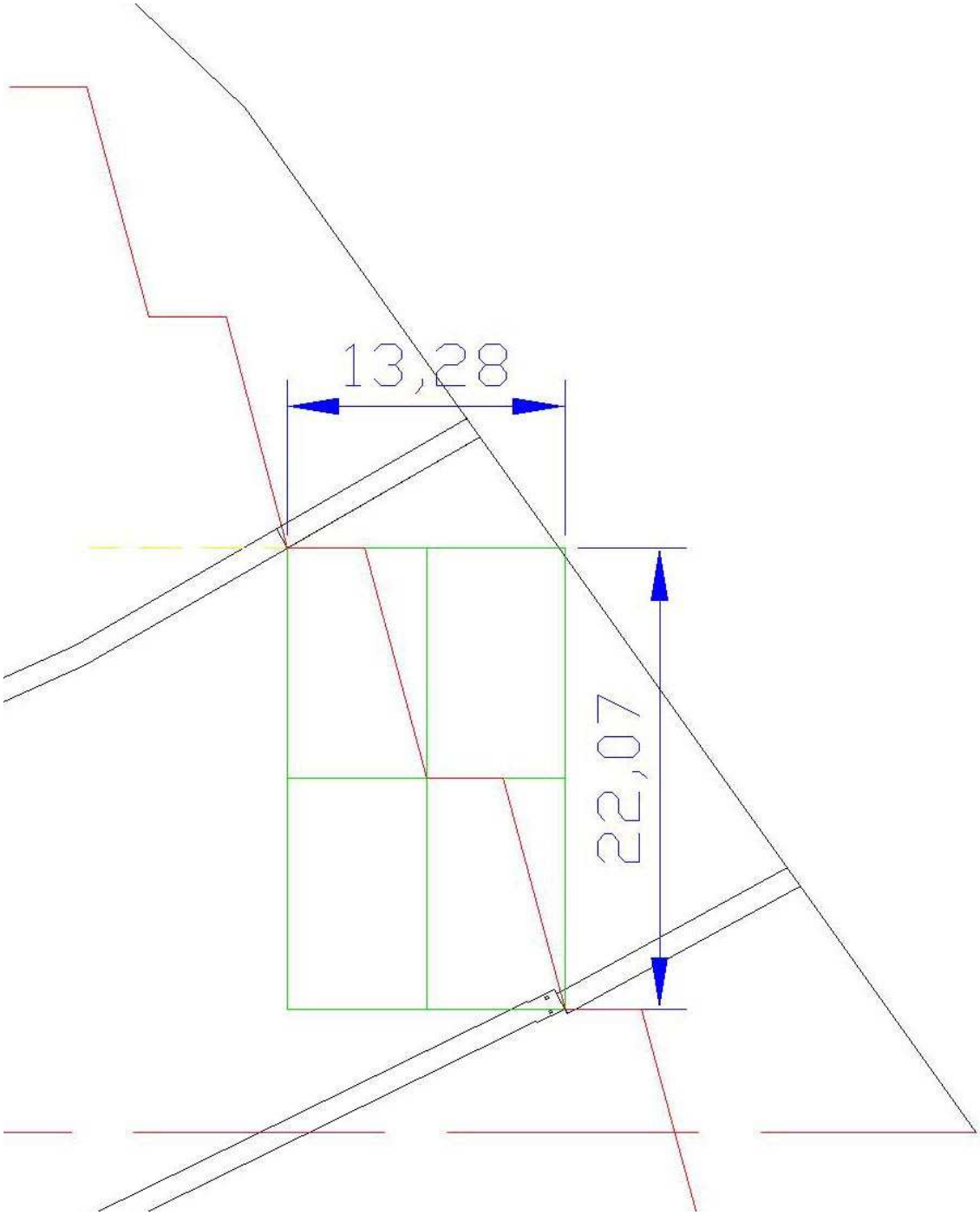
But the idea that the joints have been made to be perpendicular to the slope of the passage, is a valid hypothesis. Taking the two highest angles for the joints of 60.5 and 58.5 we have a difference of 2 degrees, compared to the CAD model which provides a difference of 1.5 degrees.

We still have to explain the continuous joints, so is there any other evidence that we can look at. Well, we have the rectangular holes south of the continuous joint. Thankfully M&R measured their position; they provide the distance from the ceiling to the bottom edge of each hole and the northern edge of each hole to the joint. The first obvious thing to notice is that the holes are not parallel to the joint; in Meidum we see the D shaped holes run parallel to the entrance face of Phase E2, here the holes do not run parallel to the supposed face of the 60 degree pyramid. When we put these holes into the cad we obtain the following result.



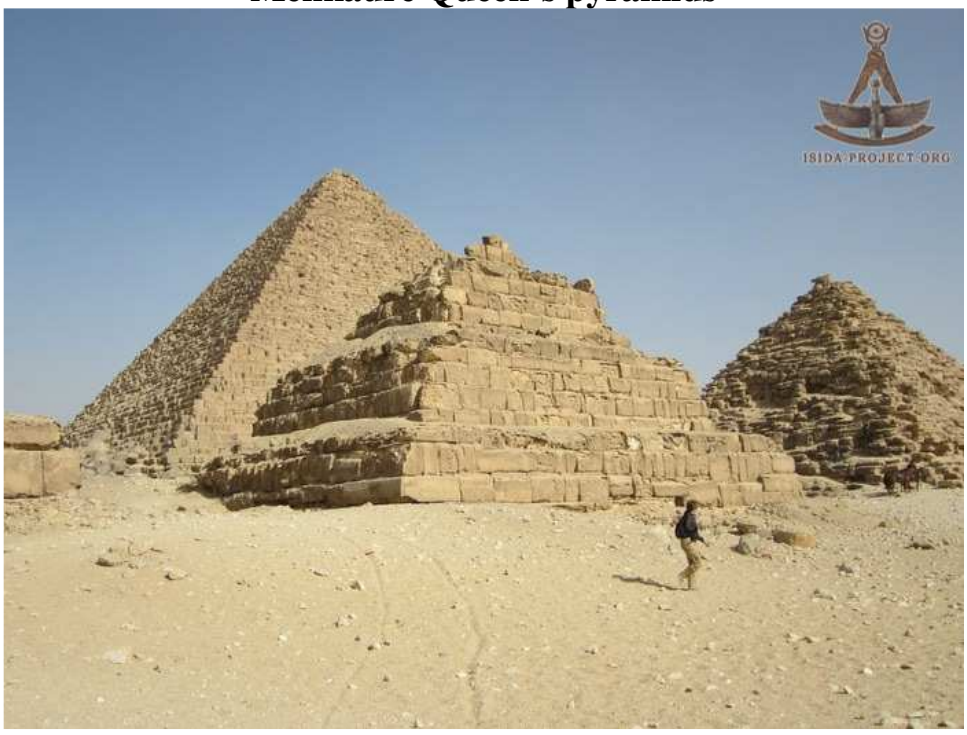
With the holes placed in our cad model and with a line extending through the bottom right hand corner of both holes, we obtain an angle of 75 degrees. Those of you who have read my Meidum pyramid paper will instantly recognise this angle; this angle is what we see in the step phases of the Meidum pyramid. If these holes were originally meant to be parallel to the facing edge of the block that they reside in, then clearly that face would be 75 degrees; therefore has the block they reside in been cut back, to enable the steeper extension to have a perpendicular joint?

In the image on the next page, I have placed a grid, whose corners originate from the bottom of the continuous joints and created steps of 75 degrees from the centre of the grid. This is just a rough experiment, for we can never know what form steps might take under the smooth casing; where the entrances exited on a step etc. On the Meidum pyramid, the steps varied in height and the layers in thickness, the variables are endless.

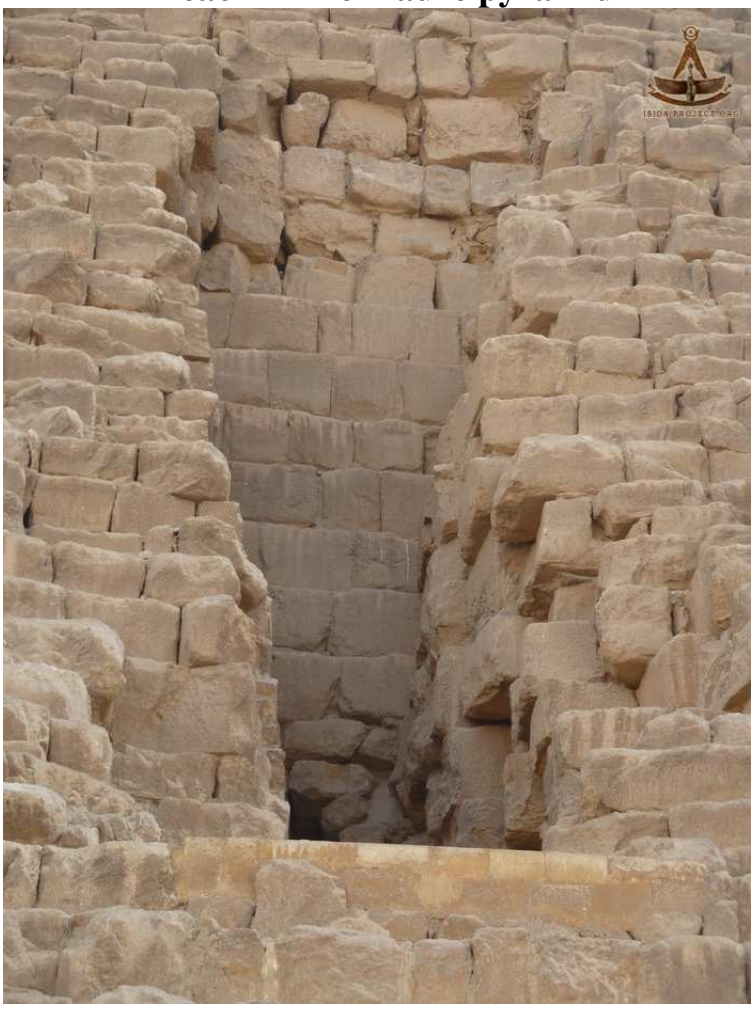

13,28
22,07

So is there any evidence of step structures under smooth pyramids? In the old kingdom there are structures, some through incompletion, or destruction that allows us a brief view of their superstructures; examples include:

Menkaure Queen's pyramids



Breach in Menkaure pyramid



In the breach of Menkaure's pyramid, M&R say;

"The nucleus of the pyramid is made in large steps. It is possible to identify the inner or outer top edges of three of these steps, which are probably the 2nd, 3rd and 4th."

"In Vyses tunnel, which we penetrated for over 15m and carefully studied, there is nothing to make one suspect faces of layers (at least two should have been seen)

Wainwright's tunnel at Meidum was informative and short of doing something like it at the Bent pyramid; we can only guess at the construction of the nucleus. That said, we cannot discount the possibility of steps occurring at these continuous joints. Let us now take a closer look at the construction of the Bent pyramid passages.

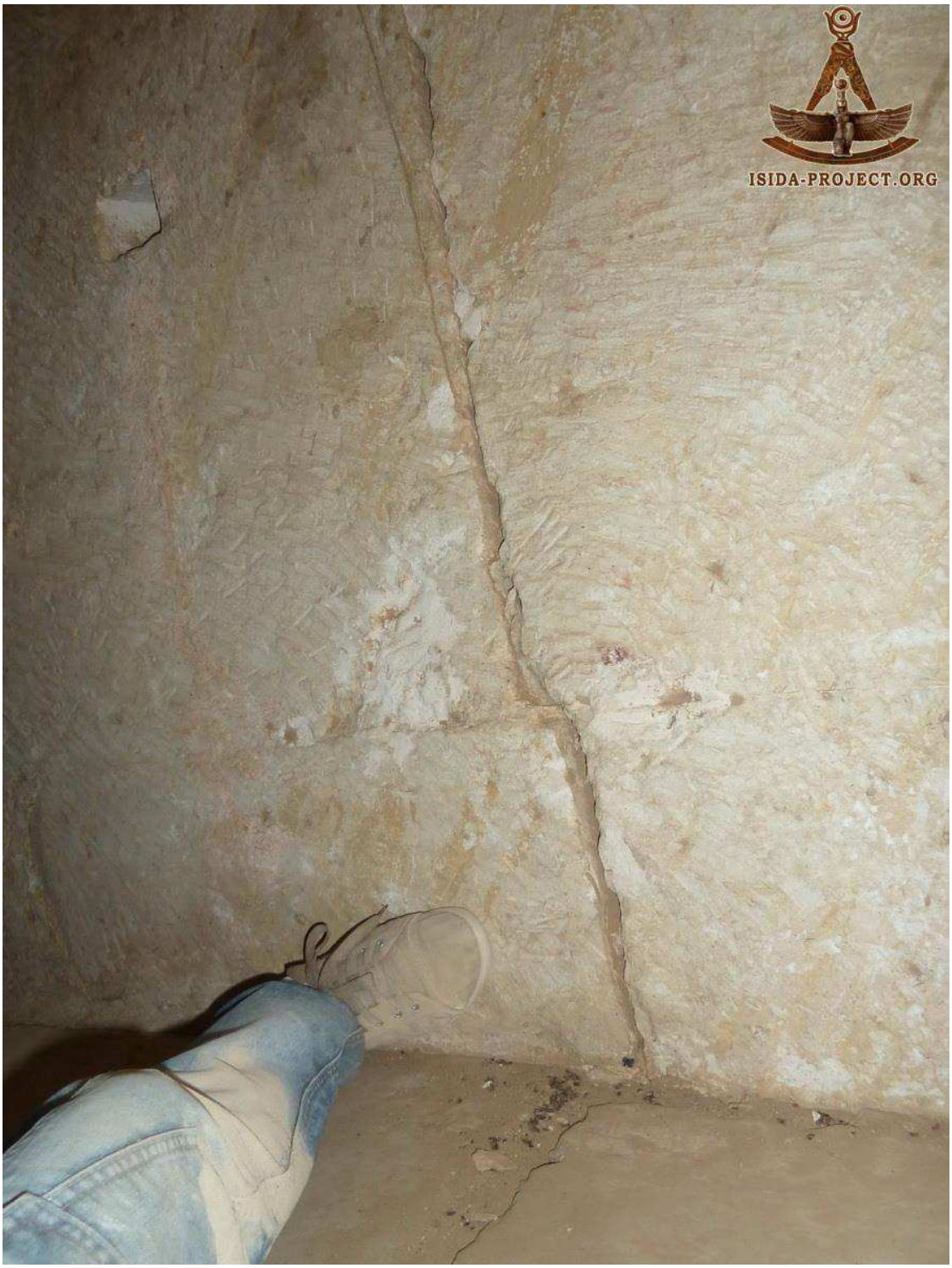
The dimensions for both north and west passages are very similar; M&R's drawings give the height of the north passage as 1.06m and west passage at 1.07m. For the passage widths they give 1.08m for north and 1.00m for west. For the western passage they say;

"Also at the end of the corridor and all along its length we have found that the floor is inserted and one cubit thick. The dimensions of the corridor change from 1.05 x 1.09m at the entrance to 1.01x1.10m towards the end"

This suggests that the bore of the passage was 2 cubits square. The passage paving slabs unlike at Meidum are inserted between the walls of the passage and are approximately 50cm; so without the paving the passage would be 3 cubits high. The side walls of the passage, like the paving slabs rest on masonry, the walls for the most part are made in two equal courses, excepting the passage walls from the so called settlement towards the entrance were Puchkov states a different construction was used, and the walls were made of single blocks. The following images should clarify things.

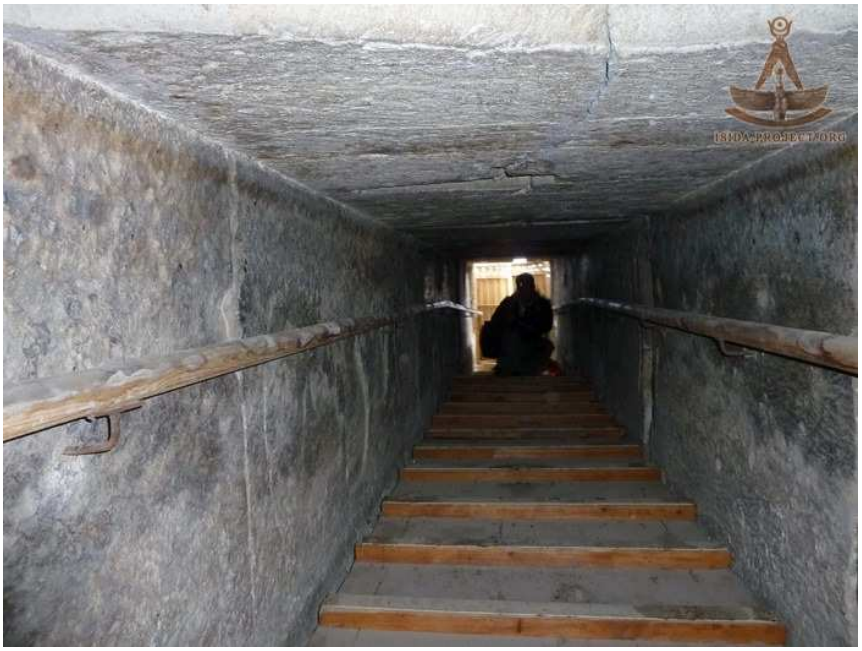
The good condition of the upper part of the west passage.

West passage continuous joint, here we see the ceiling joint meet the joint on the south wall. Also note the small square hole and red ochre line.



The continuous joint on south wall of west passage; the joint of the lower wall course with the upper can be seen and this lower course appears to protrude slightly further west than the course above and the floor joint.

The continuous joint on north wall of west passage.



Looking up the north passage, Puchkov states the walls are made of a single course from the continuous joint.

Looking down the northern passage at the continuous joint. The wall blocks immediately north of the joint have been excavated sometime in the pyramids history; the western wall block has been excavated up to 2m deep and .85m wide, the eastern wall block has been excavated to a depth of 1.1m and .75m wide.

In this view we can see how the ceiling block has been dressed down and was described by Petrie. The exposed face of the block that is the continuous joint can be seen and was measured having an angle of 60.5 degrees.

A view across the corridor at the eastern joint and excavation

Barely visible in the above images on the faces of the north passage continuous joint are stone protuberances on both walls. M&R say;

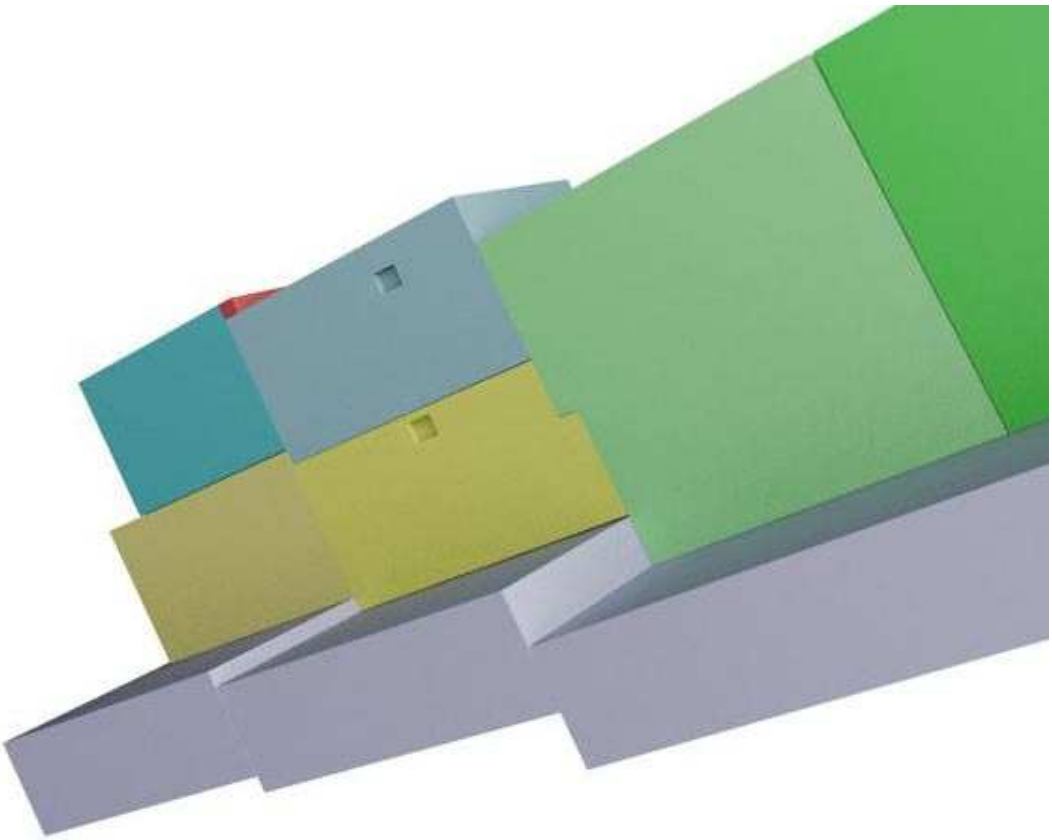
"moreover, a very strange element can be noted, shown in plate 11, fig.5 In line with the dislocation and at the floor level, the wall blocks have a distinct rough protuberance of about 10cm"

They explain these protuberances as;

"The face of the original pyramid had not yet been completely dressed: when the layer of masonry was added in order to enlarge or reinforce the pyramid, only a part on the face above and on both sides of the entrance was smoothed to make the leaning bed for the new blocks of the corridor. The remaining part hidden by the pavement was left in the rough to make a kind of bonding between the old and new masonry."

A strange feature of M&R's work is the omission in their drawings of masonry joints in the north upper passage from the continuous joint, even the large scale drawing of the entrance is devoid of joint lines; they detail the D and round holes and the walls are blank, yet with care they detail with measures the form of the joints at the end of the corridors. That they have

examined the upper passage walls is clear, they mention marks on the walls that indicated the floor level from the missing paving; they state that the D holes further up the passage on the east wall is made along a joint. How they missed Puchkov's observation of single course blocks is a mystery, especially given the location of the upper passage and the light available from the entrance. The Drawing of the so called area of settlement is likewise devoid of any joint lines, or any indication of the neighbouring blocks joints or dimensions. Likewise the second so-called area of settlement south of the continuous joint, which M&R gives as 8cm, is devoid of masonry layout. The whole area is clearly in great need of better scrutiny.
The following image gives us a rough idea of the current arrangement of the masonry at the continuous joint.



With the west wall repaired and the flooring stones removed, we see the 3 cubit high walls resting on core masonry. From Puchkov's observation we have the single green block, abutting the blocks of the continuous joint, the ones with the square holes. The lower of these blocks shows the 10cm protuberance. The small red block is an area that needs closer scrutiny, M&R say the roof block sunk 8cm, 1.4m south of the continuous joint, yet the block is 1.5m. M&R's drawing does not show the joints of the blocks

with the square holes, their drawing gives the impression that it is a singular large block with a perpendicular joint running the full height of the wall and coincident with the 8cm drop in the floor. Puchkov's work shows the horizontal joint line and therefore in the image it is shown as two blocks; unfortunately I can see no images that can clarify the position of the southern vertical joints. Likewise the vertical joint between the two green blocks is not known.

To me the 10cm protuberances on both walls are a weakness to the settlement theory at this junction.

In the image above I have raised the green block up the 23cm that M&R say was caused by settlement. Now if M&R say that the protuberances were left to make a bond between the old and new masonry, it follows that the pink area in the image above the protuberance becomes part of the green block. This means that on settlement this pink area somehow vaporises, I just fail to see how this can happen.

Though the idea of settlement at this junction is generally accepted as fact, we do have a dissenting voice in the form of Petrie, who gives the following opinion on the matter.

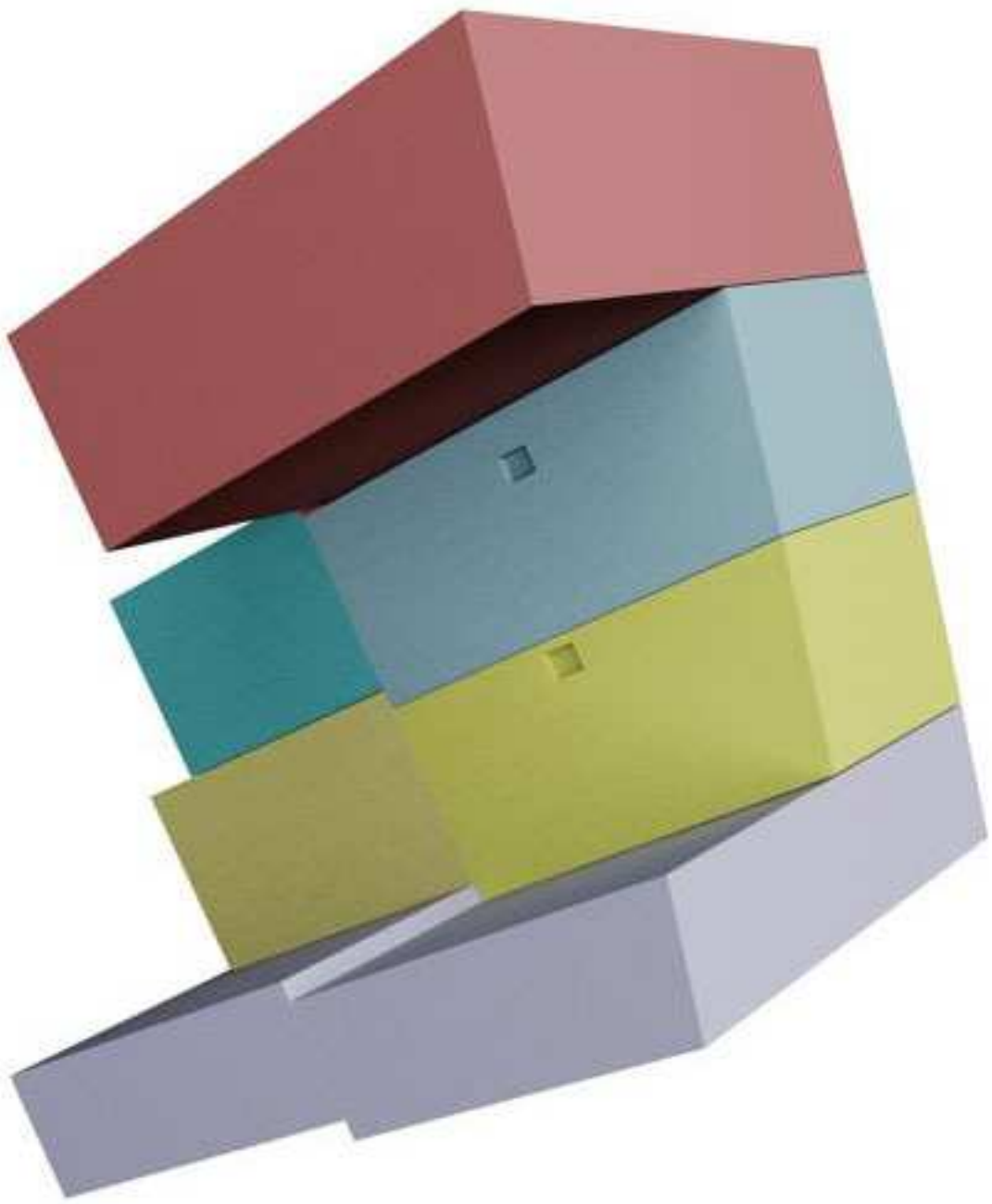
"The dislocation is at a remarkable place, where the roof and floor in their outward course suddenly turn up in a curve to a point 11.1 above the true line, and then dropping sharply, they begin again only 1.1 above the true line, and fully regain the old direction in 23 inches distance. This formation is not due to settlement, for (1) a settlement of 11 inches in such solid masonry, not far from the ground, is impossible, the more so as it would need a uniform settlement of the whole of the lower part of the passage, which should quickly cease at one point, and soon after continue at an equal amount; and (2) because the roof on the upper side of the dislocation is cut away in a slope for 23 inches, 1.1 being removed at a maximum. This shows that the builders were well aware of this formation in their time; and yet that they did not wish to smooth it all out, as if it were an accident or settlement, though nothing would have been easier for them than to have removed all trace of it. This part, like the rest of this Pyramid, needs far more examination."

I would tend to agree with Petrie, here was a person not new to settlement; he describes the movement about the Kings chamber in Khufu's pyramid in a detailed way.

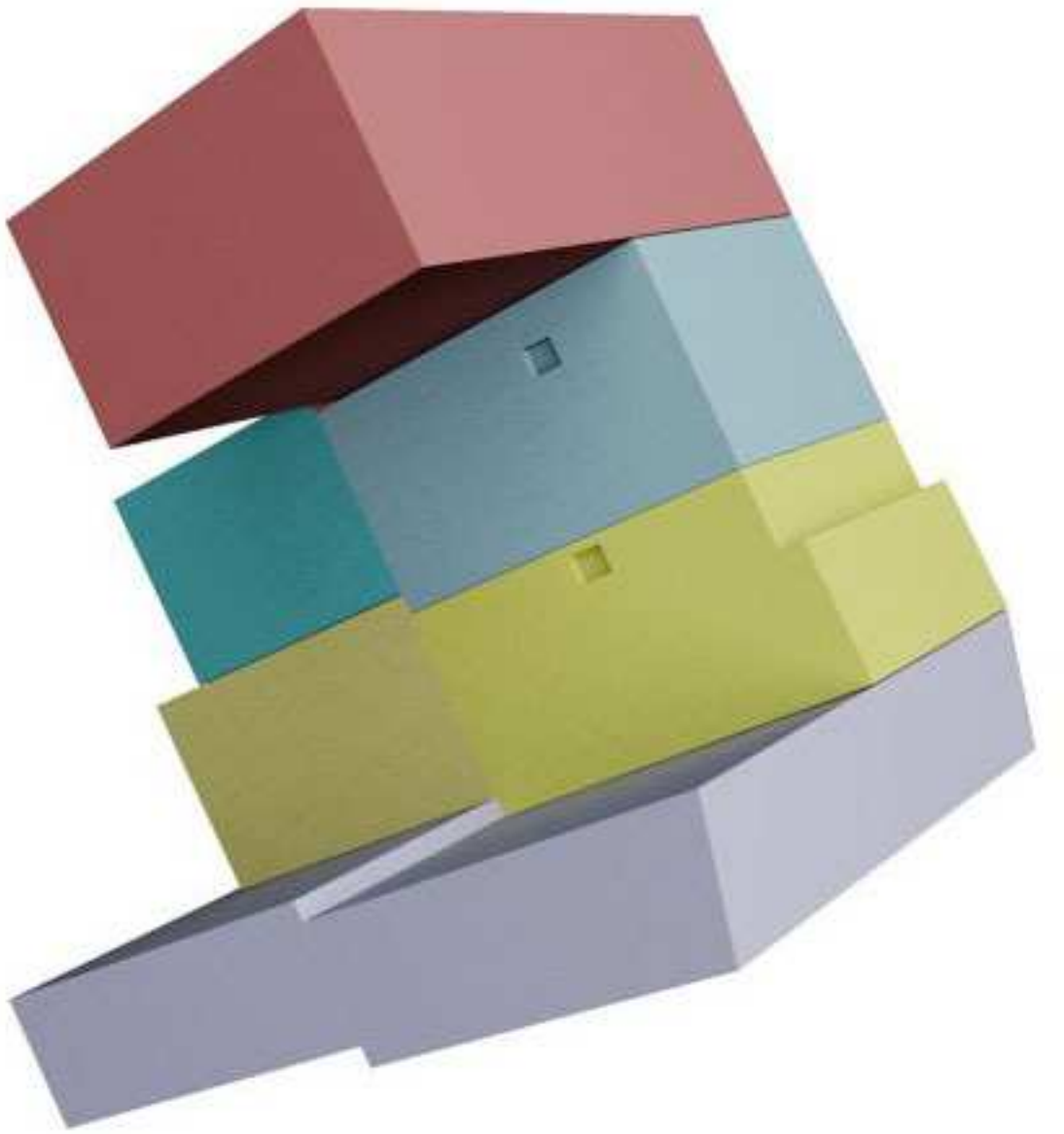
So if not settlement, what are we seeing here?

To me the simplest answer is the modification of a 75 degree step structure, and in the following series of images, I hope to demonstrate the possible procedure.

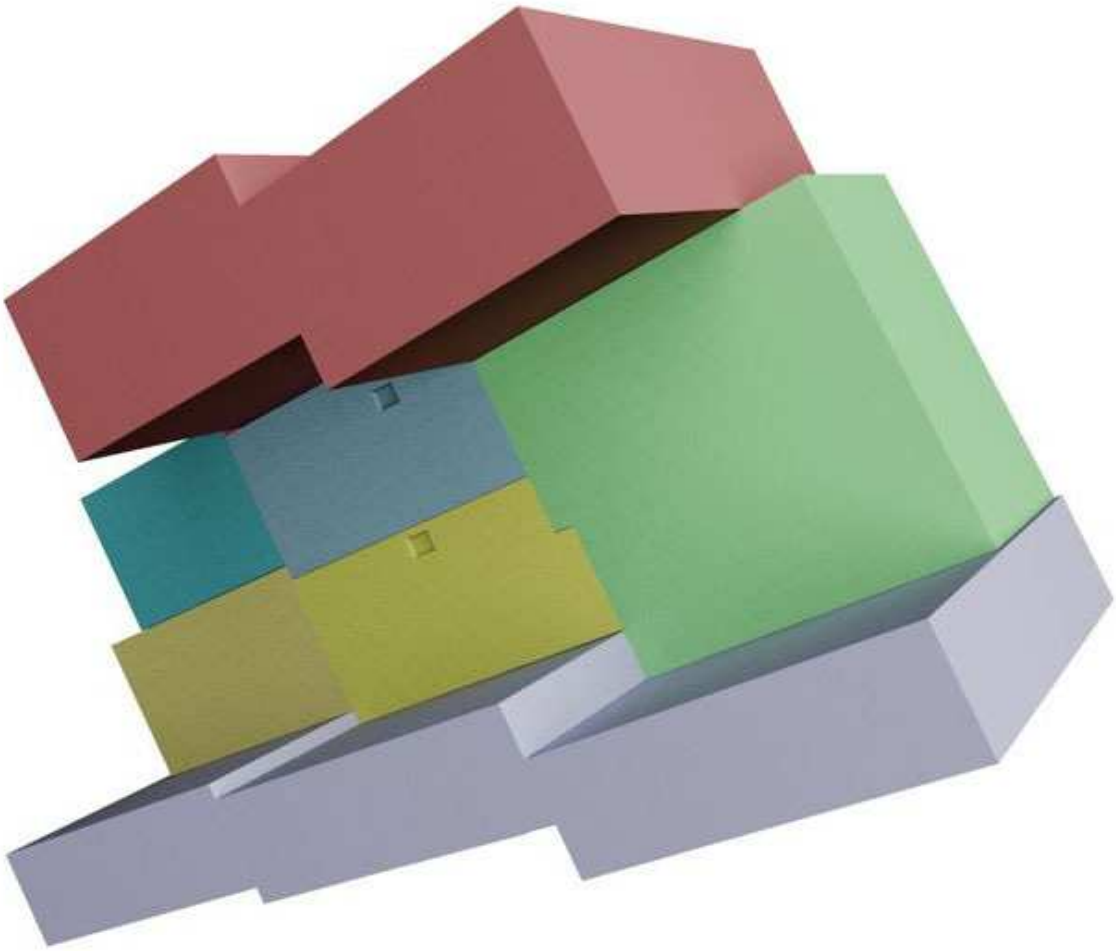
In the next image I have taken the clue from the square holes and modified the northern faces to 75 degrees, the origin of the angle commencing from the bottom of the protuberance of the lower block. A roof has been added and the paving stones that would have been inserted between the walls have still been omitted for clarity.



In the image above, the blocks have been modified to conform to that of a 75 degree step structure; the so called 8cm settlement may have been made deliberately to aid sealing the structure if required at this stage, by acting as a stop to a closing block. In this respect, it's interesting to note a similar feature thought by M&R to be a settlement in the western passage immediately south of its continuous joint, measuring 5cm.



In the image above, once the decision to proceed with the next phase of construction had been taken, the builders would cut back the face of the 75 degree blocks, to mirror the perpendicular angle of the new passage extension. The protuberances at paving level would be left to help bond the new passage masonry; the ceiling stone likewise would be cut back. The new passage extension was decided to be lower at this junction and the angle adjusted accordingly to compensate.



In the image above the new construction of the passage extension is married to the modified step phase, with the new lower ceiling block, abutting against the old cut back ceiling and upper wall stone.

In this final image, the paving blocks have been fitted to complete the passage. This basic experiment matches well with the observable features in the corridor, both roof and walls show a continuous line, though the floor block is slightly north in this model, but then even M&R's drawing shows the floor block joint further north than the continuous line. The masons doing this work will have their own solutions and methods to the task at hand in this modification, but as a proof of concept, I feel it is a valid alternative to the accepted settlement theory.

Such a feature as this would be unlikely to go unnoticed by early violators, who could have excavated the walls in search of some find. The excavations into both walls would not help the structural integrity of this area and the large voids created by the excavations, may well have helped the propagation of cracks in this area.

The continuous joint in the western passage, differs from the north in that the passage continues at the same angle and plane of the masonry that is immediately east of its continuous joint; furthermore, according to Puchkov,

the masonry of the walls remains the same as the rest of the passage in being made of two courses; but even here the above concept can work.

The question arises then, why would they build the northern passage in this way? Several ideas come to mind. They may for example have intended to eventually plug the entirety of the upper extension with stone blocks as security; the 23cm step in the floor would provide a good stop for the blocks and the increased angle could make for easier insertion of the blocks. This feature can also work in the other direction; valuable items, previously fitted, that you wished not to be removed from the lower chamber, would be safe in the knowledge that the restricted height at this junction would prohibit their removal. In this respect the granite coffers of Khufu and Khafre spring to mind as an example; where the design of their structures prevents their removal.

The slight cutaway in the roof block mentioned by Petrie might be a slight alteration by the masons to conform to the dimensions that they were given by the architect, to ensure the selected items for the lower chamber can safely pass the junction.

So if a step structure was modified, does this indicate a change of plan? Not necessarily, there is a school of thought that the pyramids were made in steps first and then cased last; but why? Two points come to mine. First, though they were exceptionally good at creating a level and square base, the hardest control point would be the centre or apex of the pyramid. John Romer makes an interesting observation on the chimney of the Bent Pyramid;

"this small shaft would have enabled the pyramid-makers to keep a sheltered plumb line at the pyramids dead centre- a most desirable reference point as the pyramid rose higher and the multiple lines and edges of a stepped pyramid were no longer available to aid in checking the architecture of the rising pyramid. Such a shaft would be the first of many similar vertical controls set up inside the early pyramids. Today, however, after the slow movement of its stonework, the Chimney no longer stands at the centre of the pyramid."

As I have mentioned earlier, the Chimney has not moved and is under the apex. (I have recently noticed in the paper by Monnier & Puchkov, that their drawing on page 29, also shows the chimney, north of the axis and in this

drawing can be seen the floor length of the upper north passage extension as 12.60m; but they are in error as M&R say *"Since the floor, in some points, is covered by debris we made a direct measurement of the ceiling, and the length we obtained was 78.60m."* And in M&R's TAV 11, they will clearly see that M&R's 12.60m measure is from the entrance ceiling, not the floor. If Monnier can amend his drawing to reflect this, he will find the chimney under the apex.)

A stepped structure, built first, would allow the builders to concentrate on the chambers and passages, the core step structure, height of steps etc, need not be that accurate and therefore built more quickly. Meidum is a good example, no accuracy was planned in the creation of the steps, yet it was successfully cased into a smooth pyramid. *(I am not suggesting this method was used at Meidum, just noting that a casing can be fitted to an inaccurate step structure, though M.Robert in 1899 found a hole in the centre of the top step, and it is thought that it might have held a rod to aid the builders as they raised the casing)* The important item of accuracy is the reference point that is the centre of the pyramid. It would be important during the raising of the stepped structure, that it was controlled with accuracy. When the stepped structure had reached the required height, the builders had a control point for the accurate casing phase.

Second, this method of stepped structure first, can be built quickly and should the Pharaoh die early, he would have at least something to be buried in. For example in the 5th dynasty pyramid of Neferirkare, in which the steps are quite noticeable, Lehner says;

"Evidence suggests that it was planned as a step pyramid, rising in six tiers of well-laid, limestone retaining walls. However, on the south and west sides some of the loose masonry remains from what must have filled in the steps, suggesting that the step pyramid might have been transformed to a true pyramid. It is certain that at a later stage the builders began to enlarge the pyramid by adding a girdle of masonry and a casing of red granite. It seems the lowest course was laid, but not smoothed, and the pyramid was never finished."

Clearly the question the reader needs to ask therefore; Was Neferirkare's pyramid, designed like this from the outset, or a change of plan to convert a step pyramid into a smooth pyramid?

Varille and Legon.

In the course of investigating this pyramid, it appears to me that there is a high probability that the internal chambers and external appearance could have been planned as a well executed scheme from the outset. On the internal chambers M&R say;

"Therefore in this pyramid the two apartments were planned from the very beginning even if we cannot understand why."

Fakhry, describes Varille's view on the structure.

"The presence of the two entrances from two different sides as well as the existence of two chambers led the late A.Varille to suggest that the bent pyramid was built on purpose in this form to be a symbol of a double pyramid and double burial, one for the king of Upper Egypt and the other for the king of Lower Egypt. Such an explanation might appeal to certain persons, but the greater number of Egyptologists have reasonably refused to accept it…."

But might Varille be on to something here and the notion of a double burial. Could the chambers each have held a sarcophagus? Take the large pyramids at Giza for example. Edrisi's accurate account inside the Great Pyramid suggests a sarcophagus in the Queens chamber. In Menkaure's pyramid we have the sarcophagus found in the lower chamber and in the upper chamber a clear recess in the floor that could have accommodated another. In Khafre's pyramid we have a chamber with the sarcophagus sunk in the floor and another chamber that certainly has a turning recess large enough to introduce another if required. Could the red and white crowns of Egypt be represented in the chambers by the use of stone, the three sarcophagi at Giza are found in red granite chambers, though Khafre's is surrounded by granite blocks. Could the remaining limestone chambers be to represent the white crown? All very tentative of course, but possibly worth more research.

Legon's work is a mathematical scheme, suggesting how the geometry of the pyramid was achieved. It fails to work on Hassan's survey, but on my Petrie model it's very close, Indeed chamber and passage arrangements inside the structure seem to show links to the outside scheme of Legon. Sadly until a modern accurate survey of the structure is done, it's a bit of a dead end. Work such as Legon's can only be tested against observable facts.

Conclusion.

The standard model to explain the Bent pyramid appears more of a statement of fact, judging from the quotes given at the beginning of this paper. This paper therefore from a simple layperson, poses no threat to the established position of senior Egyptologists. But it is hoped that should they come across this paper, a sufficient seed of doubt may arise that could lead the way for further investigations to be carried out on the Bent Pyramid.

For indeed the structure is in great need of more detailed investigation, as Fakhry rightly points out;

"The interior of this pyramid has been examined but I can never pretend that it has been thoroughly investigated or it does not need more researches in the future"

Everything seems to rest on the observations of M&R, and since their time the pyramid has lain dormant, like some sleeping volcano. Puchkov's recent work is maybe the beginning of the awakening of this structure. Dormion and Verd'hurt's recent work at the Meidum pyramid shows what can be achieved by thorough investigation, and it's highly likely such features can be found above the passages in the Bent as well.

My biggest problem is how Egyptologists can be so sure of their model, given the clearly low level of investigations carried out on the structure. How have we arrived at this level of certainty? To me, the illusory truth effect best fits the situation we see; a story started back in Perring's day and embellished further by subsequent authors, and because we fail to thoroughly investigate the structure, this illusory truth will only grow, like some good wife's tale.

When I look at this structure inside and out, I can see a clearly executed plan, with no need to invent subsidence, changes of plans or 60 degree pyramids. If it is such a failure, why did they finish it? Why build a fine subsidiary pyramid, a grand enclosure wall and stone causeway, leading to a fine temple and another brick vaulted causeway to a harbour? Is it too hard to look at this structure as a success and not a failure? It is too easy to denigrate the great engineers and builders of the 4th dynasty and suggest that they did not know what they were doing, leading to all manner of problems

like some cowboy builders. These ancient Egyptians knew exactly what they were doing, they had experience and expertise behind them; they built amazing structures that still baffle us today. They could use and work stone in a way that none of us can truly understand; yet at the same time we find fault with their work, when maybe there is no fault to be found.

The idea that the Bent pyramid could be a success will be controversial, but given the poor level of research carried out at the structure, I feel my idea's against failure and the 60 degree pyramid are just as valid as the standard model. I don't feel I am being controversial in suggesting that a step structure was built first, not a 60 degree pyramid, I have shown examples of stepped structures inside pyramids; so to me it is the simplest solution to these continuous joints that M&R mention.

Only more detailed further research can clarify the points brought forward in this paper. As a layperson getting access to investigate the Bent pyramid would not be possible and I note in Nuzzolo's work the difficulty of such a task as he says.

"Unfortunately, notwithstanding repeated attempts, the author has been unable to secure permission to enter the pyramid"

While I have many ideas on the structure, the major road block is the lack of accurate observable data on the Pyramid. Only Egyptology itself can do the necessary work required to thoroughly investigate the structure; whether they choose to do so is another matter.

My work basically echoes the view of Steve Burrows when he states;

"by structural analysis this was designed like this. It hasn't failed; this is actually a great success"

The Bent pyramid at Dahshur is a fantastic piece of engineering; is it time we gave credit to the ancient builders and wake up this sleeping giant?