The horizontal chamber stack of the Great Pyramid

Abstract

The Great Pyramid of Giza is a well known ancient structure on the outskirts of Cairo and in the previous two papers in this series regarding the building I established that there are errors in the surveying which, when corrected, allow the architectural design of the vertical placement of the pyramid's two main chambers to be identified.

In this paper I identify a procedural error in William Petrie's 1883 survey of the pyramid which, when corrected, allows the design of the pyramid's internal passage system to be understood.

In Petrie's survey he established that the internal passage system and external faces of the pyramid are constructed at a small negative azimuth. To simplify the documentation of the resulting surveying data of the internal architecture he referenced all measurements in an easterly direction to a vertical plane running through the center of the building which is parallel to the average of the azimuths of the east and west sides of the building.

I show that when a true north elevation of the Great Pyramid is established from the original survey data, that the architect's original design of the internal passage system can be identified. From this I show that the north elevation of the building and the east elevation are designed to lock together using the vertical axis of each elevation as a common reference.

During the creation of the true north elevation, and due to the systematic design of the architecture, I show that the original orientation of the center line of the gallery within the pyramid must have been along a true east west line, that the sides of the building were constructed to a logical known azimuth, and that the rotation of the building due to tectonic plate movement over the last 4700 years can be established with precision, because one of the purposes of the architecture is to specifically allow such a measurement to be taken.

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The horizontal chamber stack of the Great Pyramid

The vertical layout of the upper and lower chambers of the Great Pyramid was determined in the previous paper in this series, *The vertical chamber stack of the Great Pyramid - Part 1*[1], in which the original architectural design of the placement of these chambers was established. In addition to stacking in a vertical direction, the chambers also stack in a horizontal direction when the classic east elevation of the pyramid is combined with a north elevation using a common central axis.

In order to perform this combination the true north elevation of the pyramid needs to be created, because at present there is an anomaly in this area of the surveying.

The North Elevation of the pyramid - a surveying anomaly

William Petrie diligently analysed the external construction of the building[2], and in particular made accurate measurements of the azimuth of the base of the pyramid and the entrance passage as follows

North side	-0° 3' 20"	(d.m.s)	-0.05555°	(decimal degrees)
East side	-0° 3' 57"	(d.m.s)	-0.06583°	(decimal degrees)
South side	-0° 3' 41"	(d.m.s)	-0.06138°	(decimal degrees)
West side	-0° 3' 54"	(d.m.s)	-0.06500°	(decimal degrees)
Mean	**-0° 3' 43"**	(d.m.s)	**-0.06194°**	(decimal degrees)
Entrance passage	-0° 3' 44"	(d.m.s)	-0.06222°	(decimal degrees)

(So that the surveying values in this paper can be easily compared with those of Petrie's original work, azimuths are primarily displayed in degree, minute and second format, and distance in inches.)

These values are quite remarkable in that the orientation of the pyramid, shown by the mean azimuth of the four sides, is the same as the azimuth of the entrance passage to an accuracy of 1/3600th of a degree. When taking the surveying measurements, this would equate to a linear error of only 0.5 mm over the 105 m length of the entrance passage and indicates that the building was constructed to a near perfect level of angular accuracy, and that that accuracy still prevails today in our modern measurements.

It is therefore perplexing that when north elevations of the Great Pyramid are drawn and published that the azimuths of the internal passages are disregarded when placing the building's architectural features onto the drawings. These published 'north elevations' of the pyramid are actually elevations taken along Petrie's entrance passage azimuth and the passage system is then incorrectly shown as vertical in the drawings. To produce a true north elevation of the pyramid the coordinates of the internal architectural features need to be determined, and the easterly offsets of the passage system as it rises through the building need to be calculated from the passage azimuths. To do so involves understanding Petrie's surveying system, in which he notes[3] that:

"Whenever any point is described as E. of the center of the Pyramid, it is uniformly meant that it is that amount E. of a vertical plane, parallel to the mean of the Pyramid's E. and W. sides, and which passes through the center of the Pyramid. Similarly of similar descriptions N., S., and W."

Therefore to produce a *true* north elevation it is necessary to adjust Petrie's measurements from the azimuth of the mean plane of the surveyed east and west sides of the pyramid onto a true north-south reference plane which runs through the center of the building . From the previous table of data, the mean of the azimuths of the east and west sides is -0° 3' 55.5", and the additional data that is required to transform Petrie's measurements is the average length of the base of the pyramid, 9068.8", and the position of the pyramid's entrance in Petrie's coordinate system.

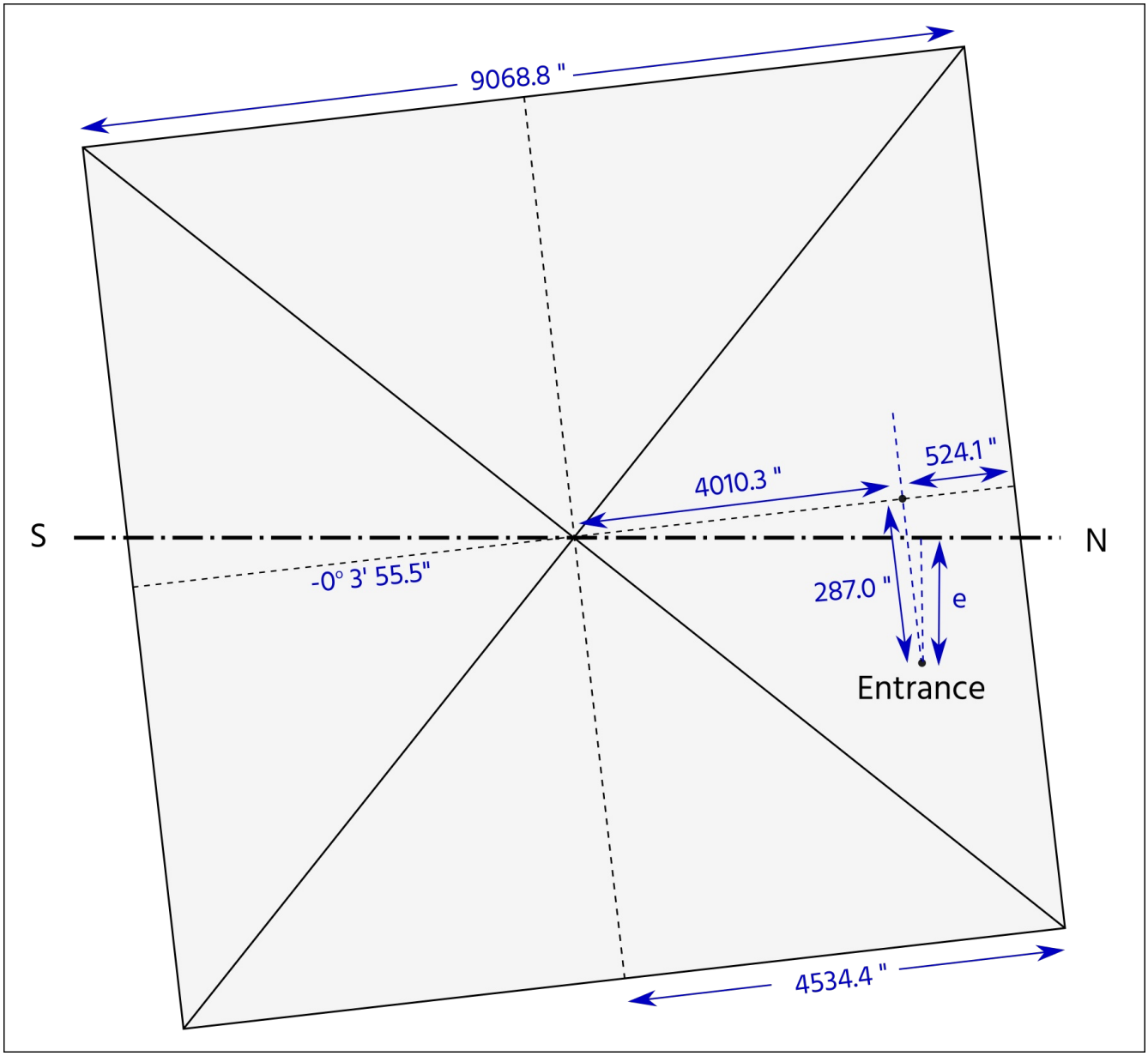

Diagram C1 - The azimuth and horizontal distances of the entrance passage and pyramid sides.

He states[3] that the entrance is 287.0" east of his center line and 524.1" inside his north face of the pyramid, and this data is shown on diagram C1, with the azimuth angle exaggerated for visual clarity.

The point labeled "Entrance" on the diagram is Petrie's defined point : it refers to the intersection of the center line of the entrance passage projected onto the non-existent pyramid face that Petrie projected up from the base of the pyramid at a semi-arbitrary angle of 51° 53' 20".

To find the actual position of the entrance on a true north elevation, the distance *e* in diagram C1 needs to be computed. Letting Petrie's mean azimuth of -0° 3' 55.5" have the letter *A*, then the entrance is 287.0-(4010.3 x Tan *A*) = 282.421" from the true N-S center line along Petrie's offset line, and therefore the distance *e* must be (282.421 x Cos *A*) =282.421", the azimuth angle being so small that the cosine is effectively 1. With the cosine being so close to 1, then the elevation alignment adjustment to true north that is being made does not effect any measurements along the N-S plane of the pyramid by more than 1/1000th of an inch and so the east elevation measurements remain correct to this margin.

Having determined the position of the entrance passage's center line relative to a true N-S axis, it is vital to also adjust the entrance point away from Pertie's virtual pyramid face and onto the physical

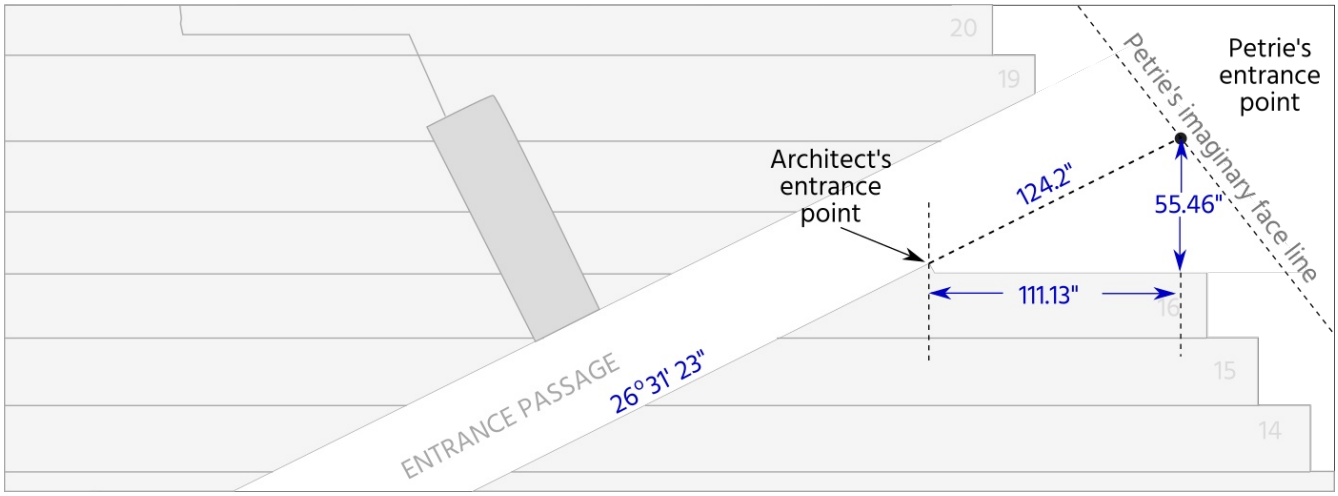

Diagram C2 - The adjustments away from Petrie's entrance point

entrance of the pyramid itself. The start of the built entrance[4] is 124.2" down the entrance passage line from Petrie's point on the virtual face, and the entrance passage was surveyed[5] at 26° 31' 23" as shown in diagram C2.

Applying these quantities to Petrie's stated position of the entrance, the center point of the architect's start of the entrance passage floor is 612.74" above the pavement of the pyramid, 635.23" horizontally inside the north edge of the pyramid (3899.17" north of center), and is 282.42" east of the true north-south axis of the building.

The passage azimuths and gallery construction

Before it is possible to determine the coordinates of the internal architecture, the meticulous system that has been used by the architects to construct the passages and gallery azimuths needs to be understood.

Looking first at the entrance passage, it is by definition open to the air at the top end and therefore when Petrie surveyed it he was able to align his surveying equipment to the Polaris star[5] and thereby determine the precise value of the entrance passage's azimuth down to the bottom of the passage. The passage is not straight, and has a lateral bend in it at a distance of 1617" along slope from the start of the floor. Petrie documented both the average azimuth of the whole passage (-0° 3' 43" ± 10") and the azimuth of the upper portion of the passage (-0° 5' 49" ± 7") , from which the azimuth of the lower portion of the passage can be determined from trigonometry, and the distances and angles involved are shown in diagram C3 in which the azimuth's numerical values are shown, and the drawn angles are greatly exaggerated.

The result is that the lower section of the entrance passage is at an azimuth of -0° 2' 5" ± 10", and this

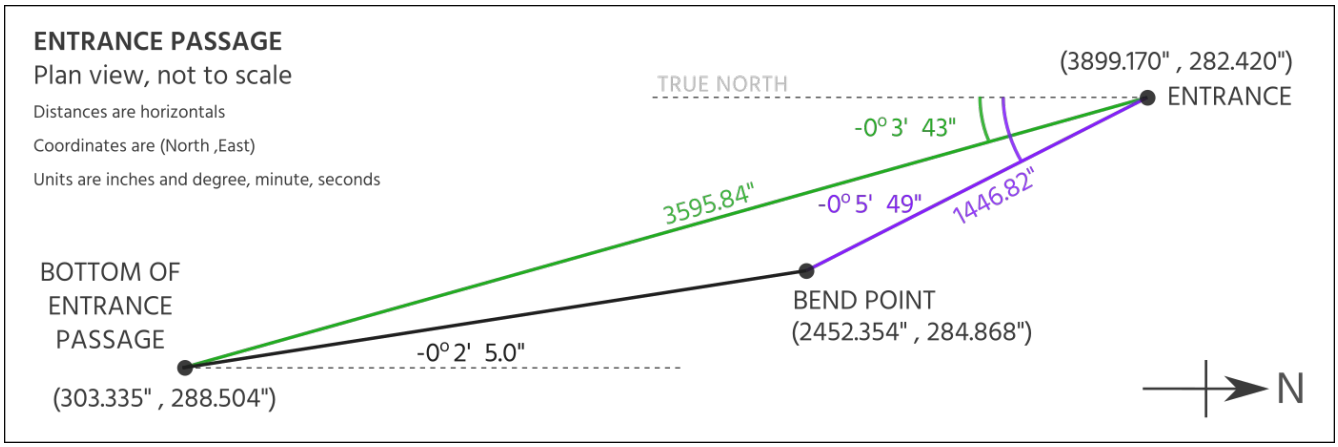

Diagram C3 - A plan view of the entrance passage of the Great Pyramid showing distances and azimuths

value is dependent upon exactly where the bend point is found down the passage. The further the bend point is away from the start of the passage, the smaller the azimuth of the lower portion becomes, and Petrie's documentation shows this bend point to be 1741" along slope from his virtual entrance point, and therefore 1617" from the actual start of the entrance passage floor. When resolved to a horizontal distance against the cosine of the passage's slope this distance is 1446.82" as shown on diagram C3.

When it came to measuring the azimuth of the ascending passage and gallery Petrie ran into the problem of not being able to continue the azimuth measurement from the entrance passage around the plug blocks which seal the ascending passage off from the entrance passage, and he lost the absolute precision of the entrance passage azimuth in the process. His reported azimuths of the ascending passage and gallery measured as one whole length was -0° 4' 0" ± 3' and his azimuth of the gallery alone +0° 1' 20" ± 3'. Although the absolute values of these two measurements cannot be taken as specifying azimuths as precisely as Petrie's external measurements, the relative value between them is accurate to the same precision found in the external measurements and is -0° 5' 20" ± 10".

Petrie noted that the azimuth of the whole length of passage and gallery combined was close enough to that of the azimuths of the entrance passage's whole length -0° 3' 43" and north side of the building -0° 3' 44" that he could conclude that they are intended to be the same.

Using Petrie's deduction that the azimuth of the gallery and ascending passage combined is intended to be the same as the azimuth of the building's faces, and if the azimuth of the ascending passage alone is taken as being the same as that of the start of the entrance passage, then the point at the top of the ascending passage where it meets the north end of the gallery can be determined from trigonometry and then the azimuth of the gallery alone calculated as being -0° 2' 1.1" as shown in diagram C4.

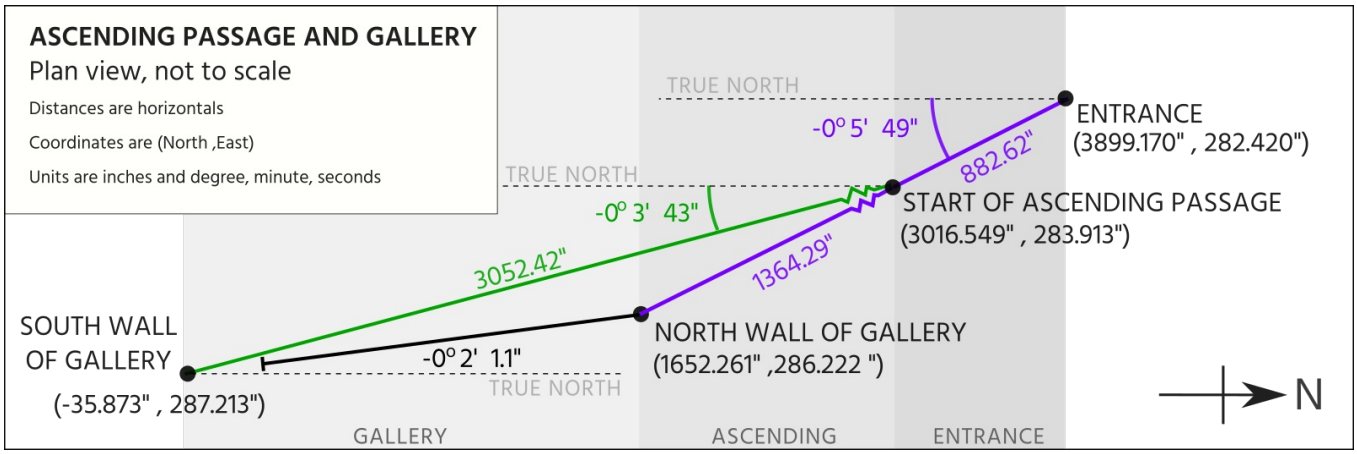

Diagram C4 - The ascending passage and gallery azimuths calculated from the entrance passage floor start point

In addition to the azimuths of the passages, this diagram contains two important features of the pyramid that are fundamental to the construction system. The first is the plug blocks at the start of the ascending passage which are shown with a wave line to indicate that this part of the passage system is variable and that it contains the adjustment that was made in the first paper in this series to correct the forced surveying error across these plug blocks. The horizontal and vertical distances involved in that adjustment were calculated by aligning to the niche feature in the lower chamber and were documented as being 64.0cm horizontally and 31.3cm vertically.

The second item in the diagram is that the south end of the gallery line, shown in black, does not connect to the south wall of the gallery because the geometry of the gallery's south wall is defined by the green line coming from the start of the ascending passage. In Petrie's work he identified that there is a half inch gap in the architecture between the top of the gallery side benches and the south wall floor and it is that gap that is being represented by the truncated black line in diagram C4.

The construction of the gallery

In the work of Professor Smyth[6] he accurately measured the width of the gallery at numerous points along its length, and concluded that the gallery is wider by a maximum value of 1.8" at the top southern end than at the bottom northern end. This correlates to the east coordinates shown in diagram C4 where the north gallery wall center is 286.222" east of central axis and the east coordinate at the top of the gallery floor center line at the south gallery wall is 287.213", the difference being 1.0" to the east, or about half the quantity measured by Smyth - an apparent anomaly.

There is a related anomaly in the surveying and that is Petrie's measurement of the azimuth of the gallery alone which, if his deduction that the combined ascending passage and gallery azimuth being -0° 3' 43" is correct and his azimuth measurement was therefore off by +17 seconds of a degree, is +0° 1' 37. The anomaly is that Petrie's gallery azimuth is positive and the analysis of the passage system gives an azimuth for the gallery alone that is negative. This apparent inconsistency can be resolved by working out that the angle between these two values is 0° 3' 38" whilst also realising that the calculated negative value is a measurement of the azimuth of the east wall of the gallery and that Petrie's measurement must have been taken on the west wall.

Diagram C5 shows a drawing of the architecture of the gallery that can be deduced from Petrie's measurements and the reconstruction of the passage azimuths and lengths from the true north elevation. The gallery is not rectangular in plan view. The west and east walls become further apart as the gallery is ascended, the center line of the gallery is very close to being set to true north and the angle subtended by the west and east walls of 0° 3' 38" appears to be intended to be the same as the overall azimuth of the gallery and ascending passage.

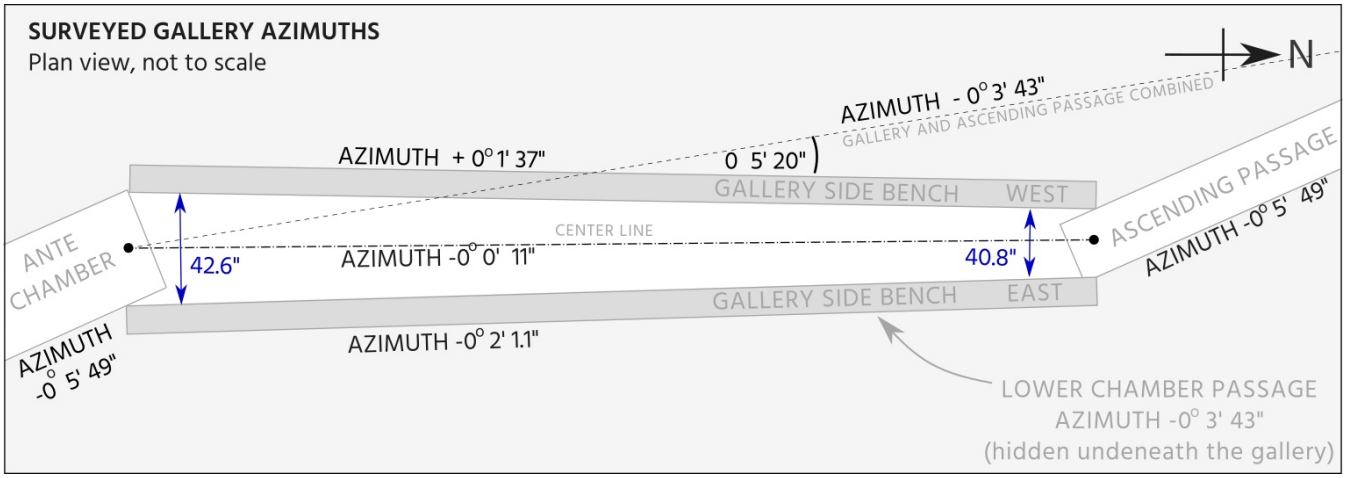

Diagram C5 - A plan view of the full resolved gallery design with drawn angles exagerated

The original azimuths

The design of the passage azimuths aforementioned specifically allows for the movement of the building over the last approximately 4700 years to be identified.

The internal angle between the ascending-passage-plus-gallery azimuth and the gallery west wall was measured accurately by Petrie as -0° 5' 20" ± 10", a value which is a constant regardless of the orientation of the building. Analysis shows that this is a highly important explicit reference value built into the architecture that informs us of the azimuth of the passage system *at the time of construction* and it is not an arbitrary value. It is intended to be precisely 1/4000 th of a full circle, or -0° 5' 24".

The entrance passage's upper section azimuth can always be perfectly surveyed because it is open to the air at the top, with Petrie measuring this value in 1883 as being -0° 5' 49" ± 7". The entrance passage has rotated from -0° 5' 24" when it was built to -0° 5' 49" in 1883, a difference of -0° 0' 25" over those approximately 4600 years.

From this it is possible to adjust the azimuth of the pyramid's sides and the entrance passage determined in the surveying as -0° 3' 43" to their values at the time of construction by deducting the same negative amount of -0° 0' 25", giving the original value of the building's azimuth as -0° 3' 18". This also is not an arbitrary value, and its exact value is ($10/2^{16}$) of a full circle, which in degree minute and second format is -0° 3' 17.75" showing Petrie's surveying of the pyramid's sides and entrance passage to have an remarkably low error margin of 0° 0' 0.25" .

The gallery original design

These original azimuths allow the design of the gallery to be fully understood, and diagram C6 shows the highly systematic azimuths of this room and its connected passages. The dictating part of the design is the angle between the azimuth of the ascending passage and gallery combined and the west wall of the gallery which has to be the same as the azimuth of the ascending passage, thereby dictating the symmetrical azimuth of the east and west side walls of the gallery of + and -0° 2' 6.25" .

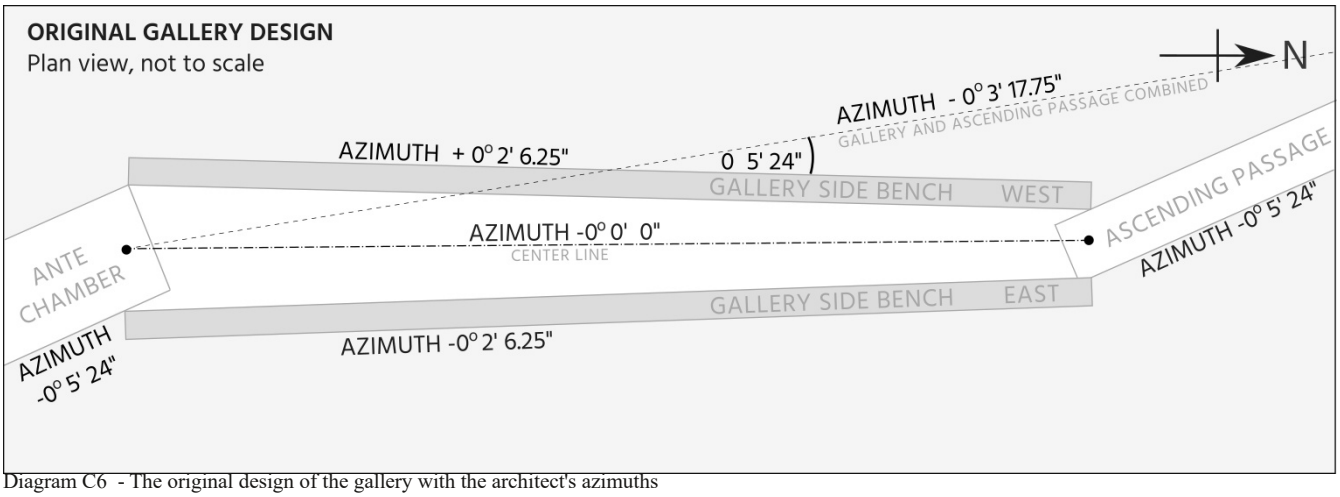

Diagram C6 - The original design of the gallery with the architect's azimuths

Using these azimuths of the side walls to compute the trigonometry of the gallery makes the top of the gallery 2.05 inches wider than the bottom of the gallery, which corresponds to Smyth's measurement of 1.8 inches to within one and a half tenths of an inch on each side of the room.

The antechamber, chambers and lower chamber passages

Before re-calculating the easterly offsets in the building's architecture from the architect's original passage azimuths, the antechamber to the upper chamber and the passage to the lower chamber need their dimensions and azimuths documenting.

From Petrie's surveying[7] the length of the antechamber passage (the distance from the southern wall of the gallery to the base of the upper chamber north wall) is 268.9". The upper chamber is 206.0" (10 cubits) from north to south, giving a total distance from the south wall of the gallery to the south east corner of the chamber of 474.9". The upper chamber has an internal wall angle[8] measured at -0° 4' 54" on the east wall, which is sufficiently close to -0° 5' 24" to deduce that the east chamber wall is a continuation of the antechamber passage azimuth. The passage is 41.20" (2 cubits) wide.

Similarly, from Petrie's surveying[9] the length of the 2 cubit wide passage that leads to the lower chamber's north wall from the top of the ascending passage floor is 1503.8" and this passage is set at an original azimuth of -0° 3' 17.75" and is connected to the gallery and to the ascending passage. The width of the lower chamber from north to south is 205.85", or 10 cubits, although this distance is not used in the horizontal design, which appears to terminate at the north wall of the lower chamber , as shown in the upcoming calculations.

The plan view

The internal passage system can now be reconstructed using the architect's original azimuths in the calculation, Petrie's surveyed distances, and the original entrance floor center point that was determined earlier, but which still contains Petrie's easterly error margin. Diagram C7 shows a plan view of the passage system with the passages colour coded according to the original architect's azimuths, and the plug block disjoint and the south end of the gallery shown as before.

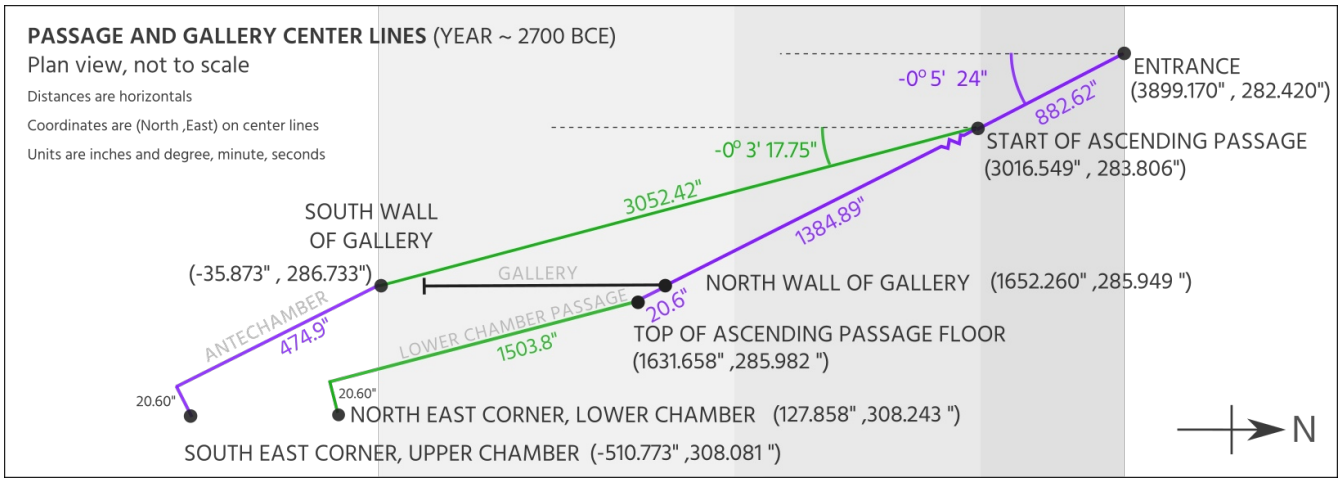

Diagram C7 - The plan view of the architects azimuths and surveyed distances

The passage system has been continued through to the two chambers in the building, and the coordinates of the corners of these chambers need to be converted to cubits to appreciate their values, using a standard conversion factor of 1 cubit = 52.33 cm = 20.602 inches.

	North (cubits)	East (cubits)
South east corner of upper chamber	-24.79	14.95100
North east corner of lower chamber	6.20	14.95369

Analysis shows that these east coordinate values for the upper and lower chambers of the building are designed to be equal and set at exactly 15.00 cubits east of the central vertical north-south plane of the pyramid. There are two errors in the values shown above. The easiest one to determine is that Petrie's surveyed entrance point needs to be adjusted by around 0.05 cubits (1 inch) to the east to eliminate his surveying error. This would bring both the east values above very close to 15 cubits and this adjustment will be done once the other error is resolved.

The second error is fascinating.

Although the discrepancy in the two east values appears small, it requires a significant error in the lengths of the passages and chambers to bring about such a small difference in this easterly value. Because the azimuth of the passages are known, and the azimuth calculations are based on logical angles, and Petrie's surveying has been shown to accurate, then there must be a relatively large error in the lengths used in the

calculations which, when multiplied by the tangent of the azimuth, produces this small error in the easterly values. The passage length change required to balance the two east values can be calculated, and it is 57.6", or 2.8 cubits at the architect's passage azimuth of -0° 3' 17.75".

In the upper chamber of the pyramid there is a 'coffin', and if it is placed centrally with its longest side facing east, that being the position in which it currently stands, then the south facing side of the coffin is 2.8 cubits from the south wall of the chamber. Indeed, this is the only 2.8 cubit length measurement in the whole passage system. This means that the pyramid's passage azimuths and angles balance when the distance to the upper chamber from the entrance is first taken to the south east corner of the room, and then brought back to the southern external plane of the coffin, along the -0° 3' 17.75" azimuth.

The value of 2.8 cubits is not an arbitrary value. It is 3 cubits minus the stack constant value *n* that was used in the vertical stacking system[1] with a value of 153/748 cubits, or 0.2045 cubits. When this piece of the system is put into place, the values of the reference points at the end of the passage system, before correcting for Petrie's entrance passage surveying error, become

	North (cubits)	East (cubits)
South facing outer plane of the 'coffin'	-22.00	14.9510013
North east corner point of lower chamber	6.20	14.9510059

The East values are now all but identical.

Petrie's reported error margin of ± 0.8" in determining the easterly location of the entrance to the pyramid can now be resolved, by setting the chamber points' easterly values to exactly 15 cubits east of the central north south plane of the building. The adjustment of 0.04900 cubits is 1.01 inches east giving the architect's location of the center of the floor of the entrance, east of a true N-S axis, as

Great Pyramid entrance
189.2584 , 13.7571 cubits (N,E)
3899.17" , 283.4294 " (N,E)

The original design of the plan view of the internal passage system of the pyramid is shown in diagram C8 where the construction starts from the south facing outer plane of the 'coffin' in the upper chamber and its intersection with the upper chamber's east wall at the simple cubit coordinates north and east of (-22,15). The azimuths then run along the east wall of the antechamber, bypass the gallery completely, join up with the entrance passage and continue along the east wall up to the entrance.

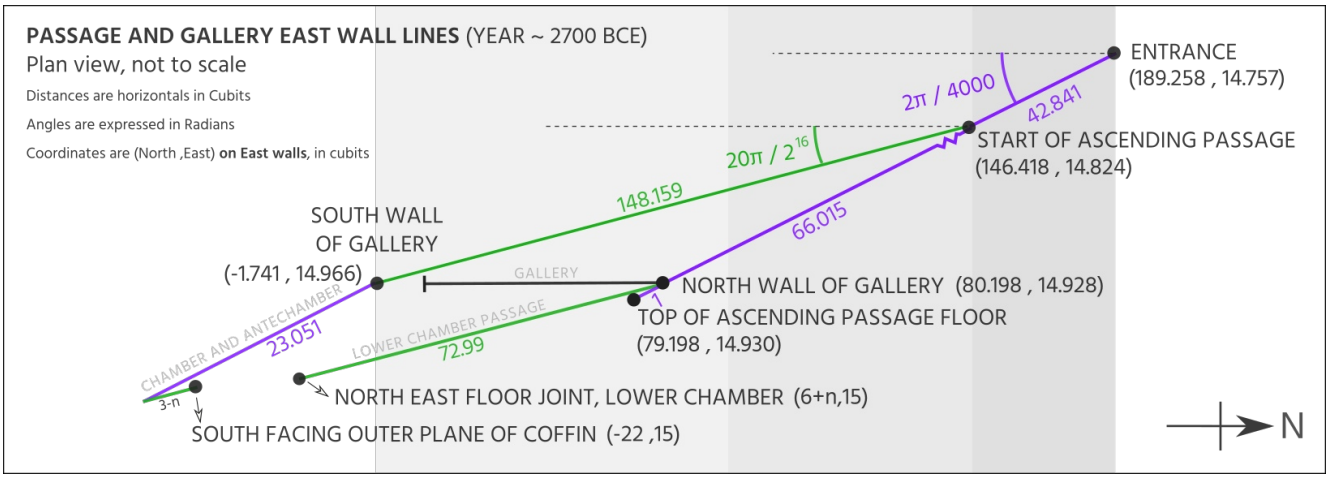

Diagram C8 - The plan view of the passage system with the original azimuths

The construction also starts from the lower chamber at coordinates (6+n,15), at the base of the door to the lower chamber, runs down the lower chamber passage at which point it splits to run up the gallery and down the ascending passage to the top of the plug blocks.

The true north elevation

A true north elevation of the pyramid can now be constructed, and a simplified version including only the entrance and the two chambers is shown in diagram C9.

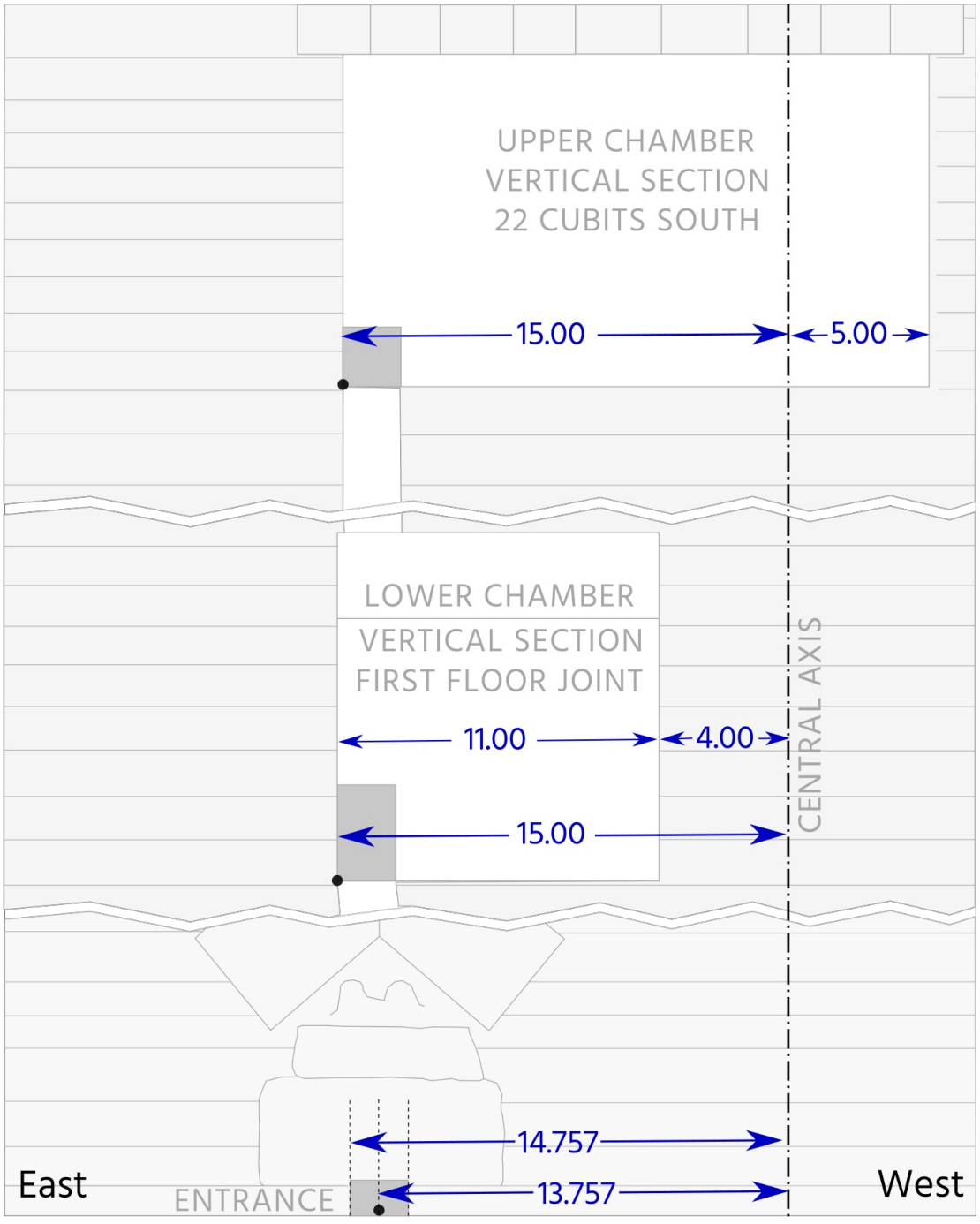

Diagram C9 - The true north elevation of the Great Pyramid

The horizontal chamber stack

Now that the north elevation has been established it can be combined with the east elevation using a single vertical axis line as a common reference, and the result is shown in diagram C10 where it should be noted that all the dimensions contain only integer cubit values and single stack constants.

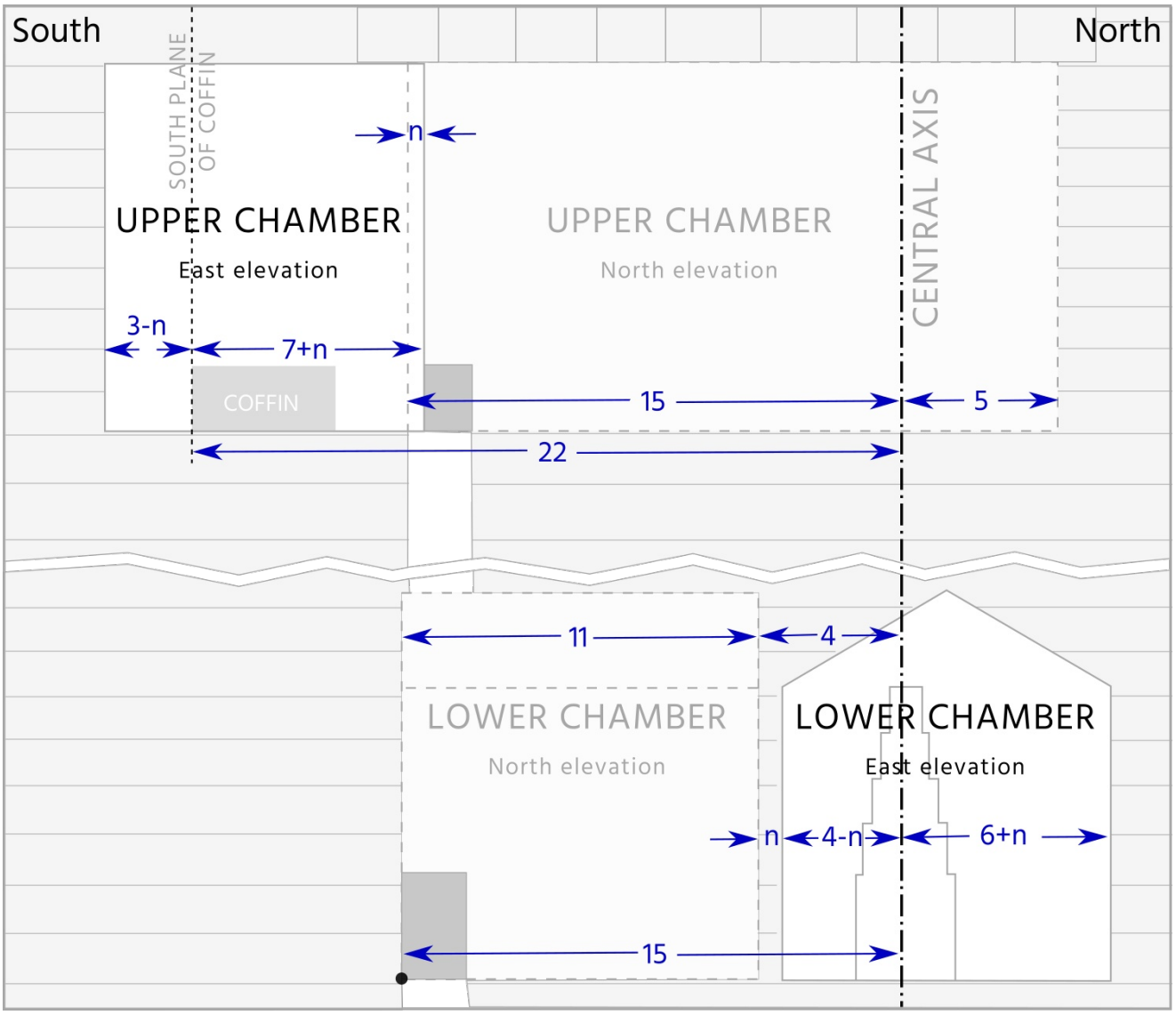

Diagram C10 - The horizontal stacking of the chambers of the Great Pyramid

In the lower chamber the walls of the two superimposed elevations have a gap between them of *n* cubits. This is a similar architectural system to that which was seen in the vertical chamber stack, where the gap above the lower chamber is *2n* cubits. Of significance is the that on the north elevation of the lower chamber the western wall is positioned exactly 4 cubits from the central axis of the pyramid because the east wall is defined as being 15 cubits from the axis line and the chamber is 11 cubits long, meaning that the vertical stacking seen in the previous paper can be precisely related to the base center of the building at ground level.

In the upper chamber the opposite system is in use, and the north elevation's eastern wall *overlaps* the east elevation's northern wall by the distance of *n*. The starting reference of the construction of the Great Pyramid's internal passages is the southern outer face plane of the coffin, which is shown in the east elevation of the upper chamber by a vertical dotted line located located at 22 cubits south of the central vertical axis.

The table of opposites

In the analysis of the north elevation of the pyramid it is apparent that the features of the upper and lower chambers of the building are always constructed in an opposite manner. The opposite nature of all the features of the two chambers are listed in table C1, wherein the architectural features that are listed and that are not part on the analysis in this paper are commonly known architectural details of the two rooms.

Feature	Upper chamber	Lower chamber
Roof	Flat	Gabled
Floor	Raised	Flat
Door	Square	Rectangular
Material	Granite	Limestone
Feature	In room ('coffin')	In wall (niche)
Wall joints	Defined	Undefined
Shafts	Un-sealed	Sealed
Wall and passage azimuth	-0° 5' 24"	-0° 3' 18"
Vertical stack	Roof overlap	Roof gap
Horizontal stacking	Wall overlap	Wall gap
Reference item	Plane	Point

Table C1 - The opposite features of the upper and lower chambers

The last line of this table shows that in the internal passage system, the starting reference item in the lower chamber is a *point* in the north east corner of the room, and in the upper chamber the starting reference item is a vertical *plane* which is concurrent with the plane of the south face of the coffin.

The lower chamber reference point is a unique location within the pyramid.

The upper chamber reference plane cuts through the whole building, and therefore provides a reference 22 cubits south of the pyramid's central vertical axis that runs through the architecture that is above the upper chamber and which allows the roof chambers that are found above the upper chamber to be connected to the resolved internal passage system.

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