The vertical chamber stack of the Great Pyramid - part 1

Abstract

The Great Pyramid of Giza, a well known ancient construction on the outskirts of Cairo, contains two principal chambers within its internal architecture, commonly known as the 'King's Chamber' and the 'Queen's Chamber'. The location of these chambers is known only from surveying measurements because no discernible architectural system which could determine the location of the chambers relative to the ground level of the pyramid has so far been discovered.

In this paper it is shown that these two chambers of the pyramid are connected to each other by a logical stack of interlocking dimensions. Furthermore, this 'chamber stack' is shown to start at the ground level of the building and continue up through the architecture to the ceiling of the roof chamber above the upper chamber.

The unit of measurement that was used in the construction of the Great Pyramid is already firmly established as being the cubit with a length of 0.523 meters and in this paper, by uncovering the chamber stack in the architecture and the logical system by which it was designed, a secondary unit of architect's measurement is discovered.

Using this secondary unit of measure the exact positions of the two chamber's floors and roofs, and the inherent design which determines their vertical position relative to ground level is documented and in so doing, the need to refer to surveying measurements to determine the vertical location of many of the internal architectural features of the pyramid is removed.

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The Great Pyramid papers

The vertical chamber stack of the Great Pyramid - Part 1

The location of the two principal chambers in the Great Pyramid of Giza is known solely from surveying measurements of the building, with no discernible architectural system dictating their positioning having been determined. In the paper "*Surveying errors within the Great Pyramid of Giza*" [1] it was shown that there are errors within the current surveys of the building which occur due to the difficulty in connecting the external and internal features of the building across the plug blocks of the ascending passage.

Once these errors are corrected and the vertical and horizontal location of the interior surveying of the building has been adjusted, it is possible to understand how the positioning of the pyramid's chambers has been designed, to the extent that the surveying can eventually be disregarded and the architect's planned location of the chambers determined.

There are several features of the pyramid's architecture that are referenced in this paper which need to be introduced at the outset so that the explanations that follow can be understood by someone unfamiliar with the terminology of the various sections of the building.

The external pavement

Surrounding the Great Pyramid of Giza is a limestone pavement which has a thickness of around 52 cm or 1 cubit and which is renowned for being remarkably level. The horizontal top of this pavement is the reference datum that is used in the principal surveys of the building and in particular in the survey of William Petrie, which is referenced on several occasions in this work.

The raised ground level

Whereas the top of the external pavement of the pyramid is horizontal on all four sides of the building and the pavement's thickness reasonably consistent, beneath the center of the pyramid the bedrock is at a considerably higher level. The pyramid is effectively built on an artificially created hill.

The well shaft and cave

There is a rough tunnel that has been carved out of the core masonry of the building and then down through the bedrock which is commonly known as the 'well shaft'. At its top, this tunnel starts within the large gallery room of the pyramid and at the point where it crosses into the raised ground level bedrock there is a cave area. The tunnel is roughly carved in its entirety except for the section where it opens up into the cave, where a number of dressing stones have been placed on all four sides of the tunnel to produce a short section of vertical stone walls giving the tunnel a square horizontal cross section at this point. The altitude of the raised ground level mentioned above is known only from the measurements that have been taken down this rough well shaft.

The upper chamber floor

The upper chamber of the building is constructed and finished to a very high standard with polished wall surfaces apparent within it. However, the granite floor of the room is unusual in that it is made up from distinct pieces of stone which all have slightly different thicknesses, resulting in the top surface of the floor being uneven. The north west corner of the room's floor is several centimeters higher than the south east corner of the room.

The upper roof chambers

Above the upper chamber of the pyramid are five roof chambers which have the same length and width as the upper chamber but which are only about one meter in height. These upper roof chambers are not accessed via the constructed rooms of the pyramid, but via another roughly carved out tunnel which leads from the roof area of the gallery in the building. These roof chambers are particularly difficult to access through this tunnel, and are connected to each other by a vertical tunnel section which is also very roughly cut out of the core masonry of the building. Consequently no surveying has been possible to determine the exact location of these roof chambers relative to the other architectural features within the pyramid and that they are directly above the upper chamber is no more than an assumtion.

The pyramid's internal architecture, initial measurements

It has already been determined by previous analysis of the pyramid[2] that the point in the entrance passage roof where it intersects with the roof of the ascending passage (Diagram B1, point A) is located exactly 11 cubits vertically above the pavement base reference level outside the building. Petrie's surveying of the building[3] shows this point as being 575.2 cm (226.4") above that base reference level, from which a derived value for the cubit measure within the pyramid must be 52.3 cm.

From this juncture onward all dimensions will be displayed in cubits in order to explain the design of the chambers in the architect's measurement unit, with the conversion factor of 52.33 cm being used to convert into metric units.

After the surveying of the internal architecture has been corrected for the errors, by adjusting the vertical position by -0.5981 cubits (-31.3cm) as determined in the previous paper in this series, it can be seen that the level of bedrock through which the well shaft passes is also located at 11 cubits above the ground within the tolerances of the surveying.

The floor of the lower chamber of the pyramid was surveyed by Petrie[4] as being 40.50 cubits (834.4" +/- 0.3") above the ground, and after error adjustment its surveyed location is 39.96 cubits above ground level. These fundamental starting points for the analysis in this paper are shown in Diagram B1.

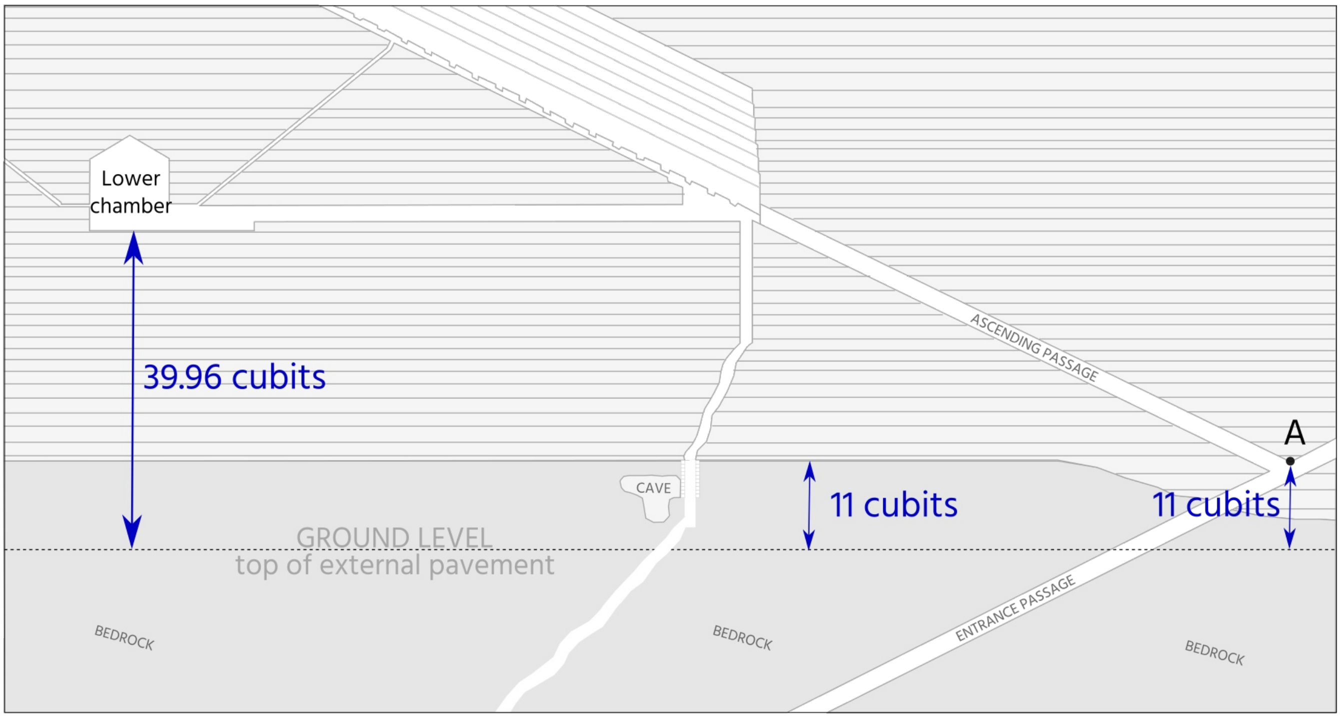

Diagram B1 - The initial measurements of the chamber stack

Unfolding the lower chamber

The dimensions of the walls, floor and roof of the lower chamber were accurately determined by Petrie[5], and converting his measurements to cubits at 20.602 inches to a cubit, the following values are obtained

Width from North to South	10 cubits	(205.85")
Depth from East to West	11 cubits	(226.47")
Height of walls	8.96 cubits	(184.47")
Gabled roof length	5.80 cubits	

with the gabled roof length on each side of the chamber being calculated from the surveyed roof angle of 30.44 degrees, which is the average of Petrie's four surveyed angular values.

The design of the chamber's vertical location becomes apparent when the lower chamber is unfolded, in the same manner that one would unfold a cardboard box into a flat piece of card. Diagram B2 shows the lower section of the pyramid with the lower chamber's walls, floor and roof unfolded in this manner. Of particular note is the unfolding of the roof, which has been done in two ways on the diagram. On the stack on the right of the chamber, the two stones which make up the two sides of the gabled roof are unfolded individually, and on the stack on the left the roof has been unfolded as though it were a flat roof which would run from the top of the chamber's north wall to the top of the south wall. The cave and the well shaft are shown horizontally translated to the south by an arbitrary distance for ease of reference.

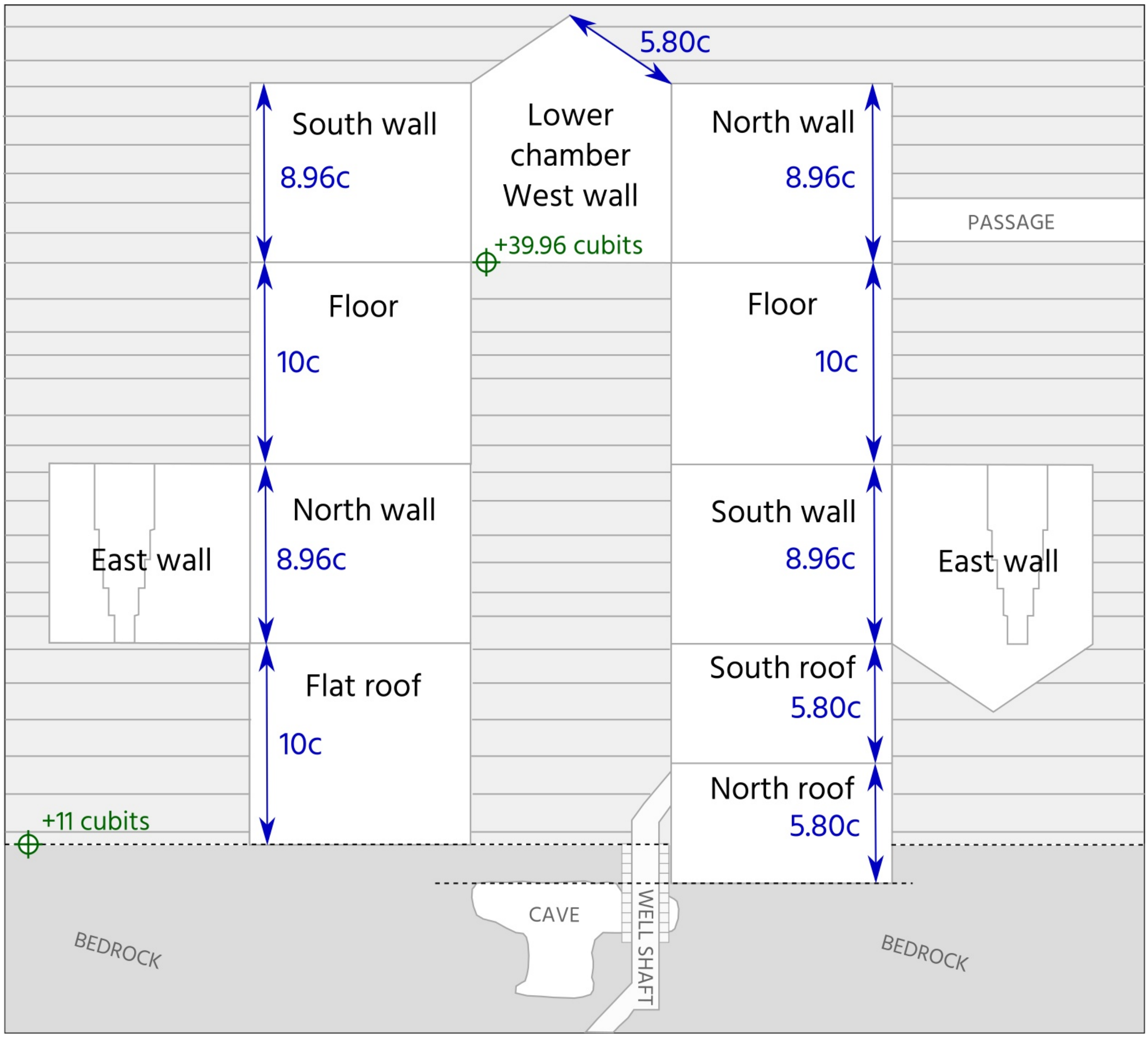

Diagram B2 - The lower section of the chamber stack

The unfolded chamber stack on the left sits perfectly on the 11 cubit high raised ground level of the pyramid, giving the height above the pavement of the lower chamber floor correctly as 11 + 10 + 8.96 + 10 = 39.96 cubits. The cave in the well shaft fits the unfolded chamber roof sections on the right side stack to perfection, as shown by the dotted horizontal lines on Diagram B2, and therefore the small square blocks of stone in the well shaft, 4 on either side between the dotted lines, must be the same length as the excess distance that the gabled roof extends below the 11 cubit high ground line when the chamber is unfolded in this manner. These 4 blocks of stone can therefore be transferred up onto each side of the gabled roof of the lower chamber, giving the construction shown in Diagram B3.

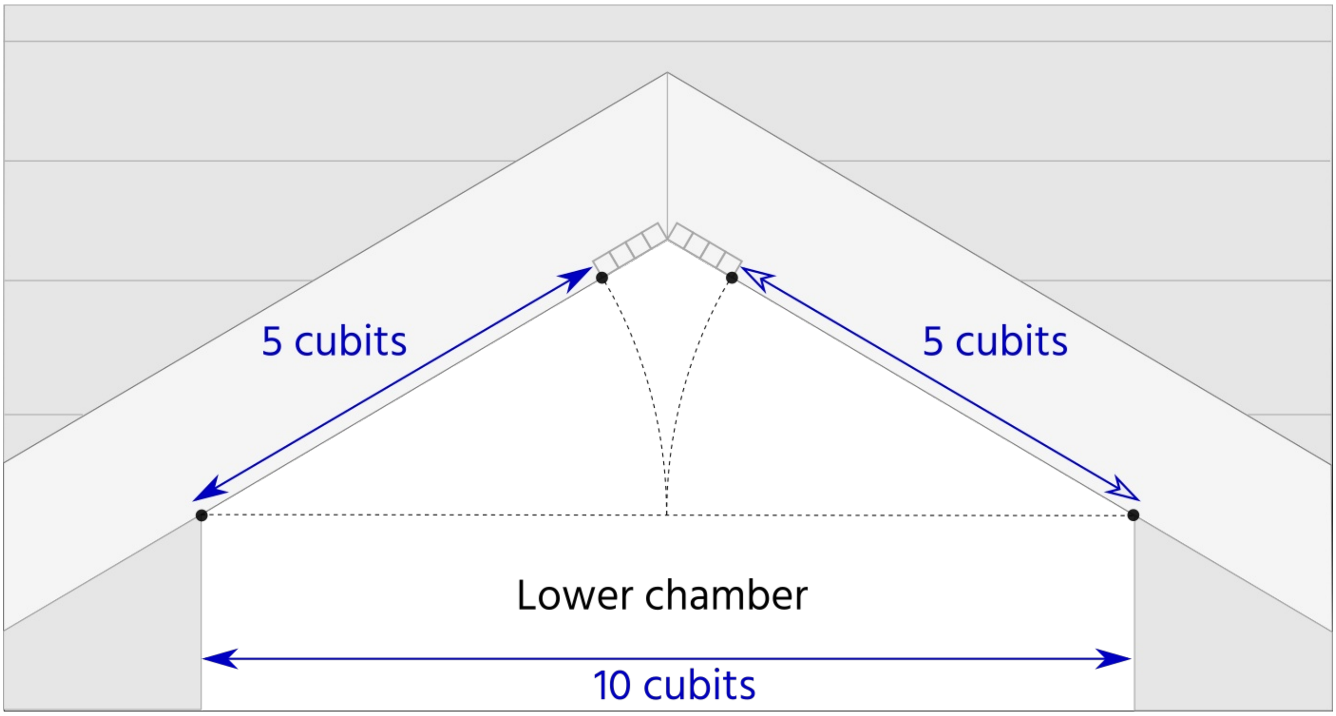

Diagram B3 - The gabled roof and measures in the lower chamber.

Diagram B3 shows the gabled roof of the lower chamber of the Great Pyramid, and the excess length of the two sides of the roof from the unfolded stack marked off as 4 units of measure on either side. From Petrie's surveying of the angle of the roof, trigonometry can be used to determine the length of these stones, which are listed below against the four surveying measurements of the roof's angle documented by Petrie[6] and which show an average length of 1/5th of a cubit.

	Roof Angle	Stone length (*n*)	
North side, east end	30^{o} 48'	0.2052	(cubits)
North side, west end	30^{o} 14'	0.1968	(cubits)
South side, east end	30^{o} 33'	0.2015	(cubits)
South side, west end	30^{o} 10'	0.1958	(cubits)
Average length		**0.1998** ± 0.05	(cubits)

This measurement length occurs again in the upper chamber and is a *fundamentally important part* of the pyramid's architectural design. I will call it the 'stack constant' and refer to it by the letter *n*. As the successive parts of the pyramid's architecture are uncovered, the stack constant's initial value of 0.2 cubits will become significantly more refined in two distinct stages.

Unfolding the upper chamber

In the upper chamber of the building, the first point of note is the *raised* floor of the chamber which, when the architecture of the pyramid was first being documented in the 18th and 19th centuries, was noticed because three of the floor stones at the west side of the chamber against the north wall were 'missing', as shown in the Diagram B4.

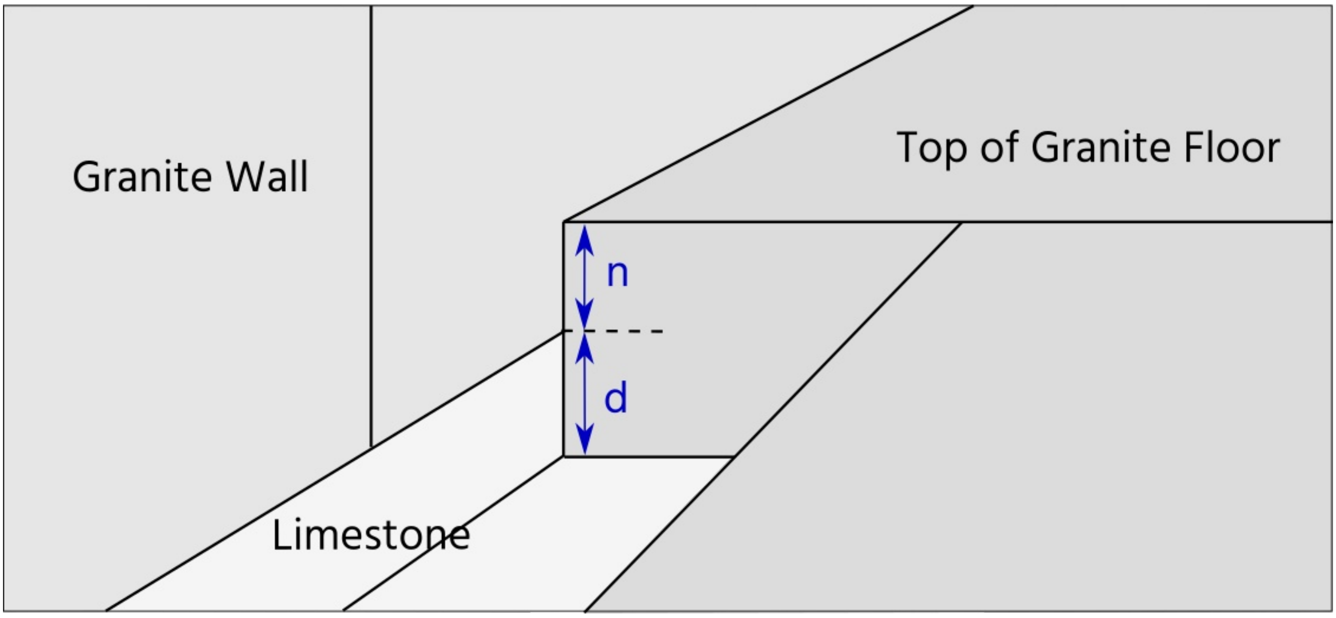

Diagram B4 - The raised floor in the upper chamber (after Smyth Plate 13).

The floor of the chamber is built upon the limestone core masonry of the pyramid, the value of *n* on Diagram B4 being around 4.25 inches and the value of *d* being around 5.5 inches . The height of the floor above the base of the wall and the system that has been used to layout the vertical construction of the upper chamber can be understood by looking at the vertical measurements in the south-east corner of the room where the irregular floor is at its lowest point relative to the side walls. Diagram B5 shows a vertical section through the south east of the upper chamber, with the various distances shown in cubits.

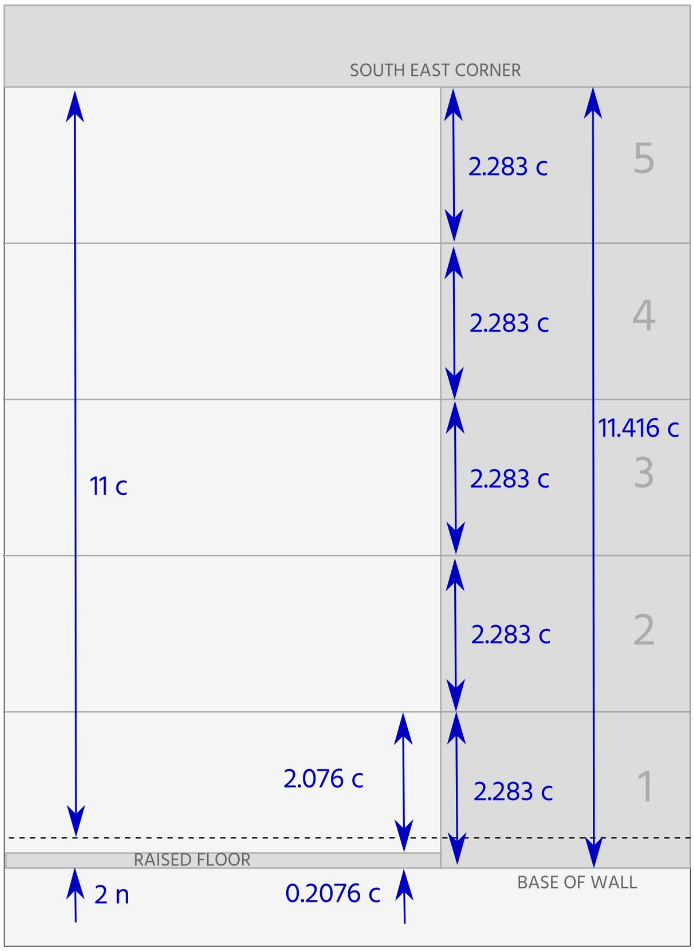

Diagram B5 - The heights and system of the walls of the upper chamber.

The floor measurements on this illustration are taken from the work of Prof. Smyth[7] and the total height of the walls is taken from Petrie's work[8].

The height of the chamber walls was surveyed as 11.416 cubits (235.2"). There are five levels of masonry making up the full height of the walls, each of identical height, and therefore each of these levels is 2.283 cubits in height. In the south-east corner of the room, the lower wall level is divided into 11 parts, 10 of which make up the portion of the wall above the floor of 2.076 cubits (42.7"), and the 11th part of 0.2076 cubits (4.27") being the section of the wall below floor level. This value of 0.2076 cubits is close to the upper bounds of the stack constant unit defined in the lower chamber, *n*, of 0.205 cubits, the difference between them being 1mm and they can be assumed to be intended as being the same value.

Therefore in order to minimise surveying errors for the full height of the upper chamber *from the base of the wall*, rather than express the total height as 55*n*, the surveyed height of the walls of the upper chamber can accurately be expressed as 11 cubits + 2n, and this is shown on the left side of Diagram B5 .

The upper chamber can now be unfolded in a similar manner to the lower chamber, paying particular attention to the floor, which does not unfold as a 10 cubit wide section because the vertical raised sides of the floor above the base wall level also need to be unfolded. The floor of the chamber unfolds into a section which is 10 cubits + 2*n* in length from north to south and 20 cubits + 2*n* from east to west.

The result of unfolding the upper chamber is shown in Diagram B6, with the lower chamber shown at the bottom of the illustration, the individual section heights marked on the right side of the chamber and the total height of the unfolded stack on the left.

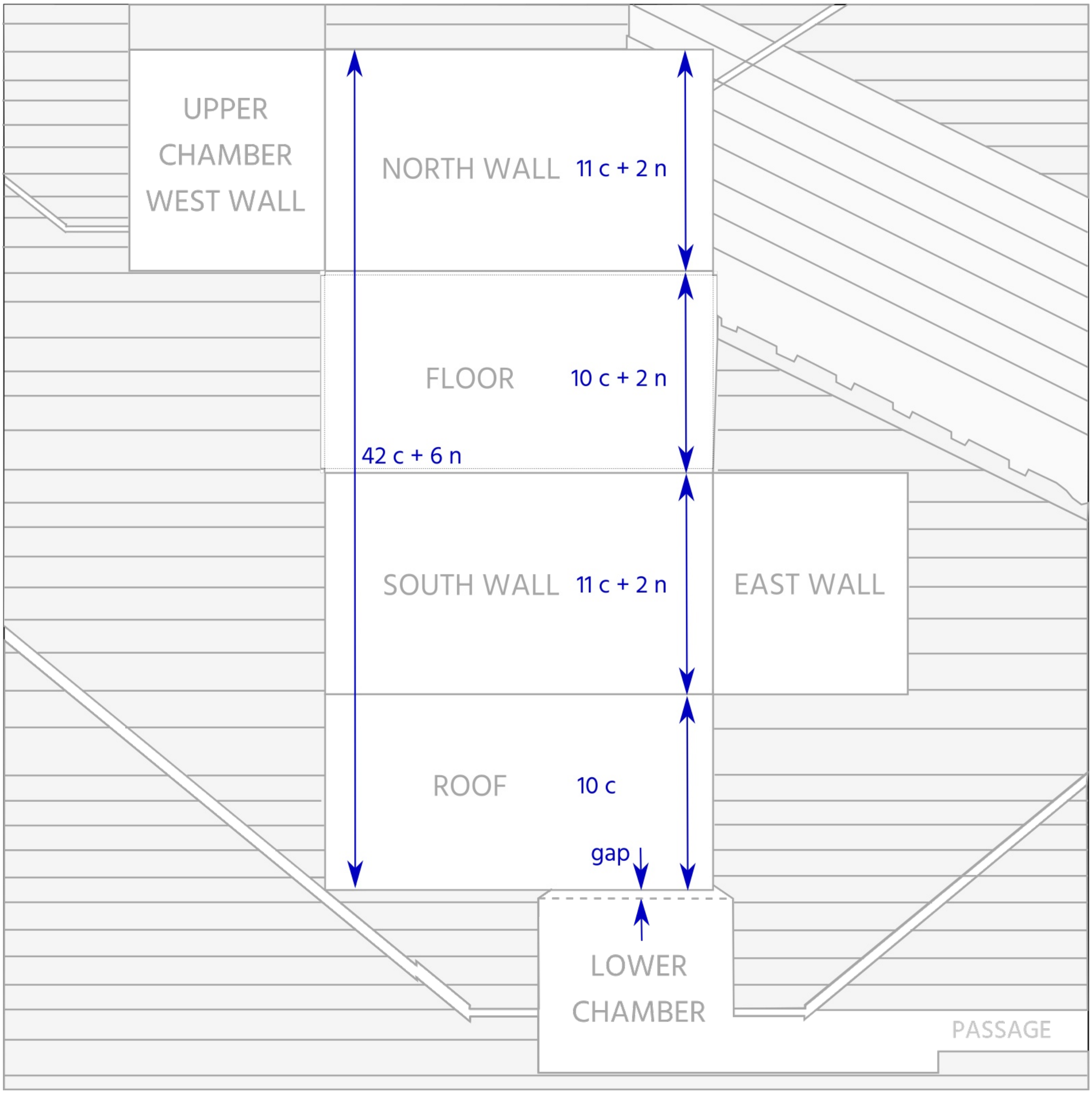

Diagram B6 - The unfolded upper chamber with units 'c' (cubits), and 'n', the stack constant

After unfolding the upper chamber it does not meet up with the top of the walls of the lower chamber. The gap between the bottom of the unfold and the top of the lower chamber walls can be measured from Petrie's excellent surveying of the building. (Because this calculation is being performed to determine the relative distance between the upper and lower chambers, Petrie's unadjusted raw data from his book can be used for ease of reference.)

Height of upper chamber walls	235.20 "
Base of upper chamber walls	1688.50 " above ground level
Height of lower chamber walls	184.47 "
Floor of lower chamber	834.40 " above ground level

The height difference between the top of the upper chamber walls and the top of the lower chamber walls is therefore (1688.5+235.2) - (834.4+184.47) = 904.83 " or 43.919 cubits. Deducting from this value the height of the unfolded upper chamber stack of 42 c + 6 n or 43.246 cubits, gives the gap as 0.673 cubits, using the value for *n* from the upper chamber of 0.2076 cubits.

If you look at the logic of unfolding the upper chamber in diagram B6, you would expect the gap to be 2*n* units in height, but from the surveying it can be seen that this is not the case. The reason for this is that there is a sophisticated (on the part of the architects) adjustment to be made to the stacking system which, as well as rationalising the gap between the lower and upper stacks, also explains the design of the upper chamber of the pyramid.

The design of the upper chamber

The design of the upper chamber is exactly the same as the design of the roof chambers above it as shown in Diagram B7 where, for any given chamber, the stone that makes up the horizontal and perfectly finished ceiling of the chamber below is also the stone which makes up the unfinished and uneven floor of that particular chamber. The only difference between the ceiling chambers and the upper chamber is the thickness of the stone in question.

The underside of the upper chamber floor stones is perfectly level and the upper face of the floor stones, upon which you walk when entering the chamber are deliberately uneven and unfinished. Their uneven nature has been put down to earthquakes in the work of Smyth and other scholars, but this is not the case - their tops are uneven by design, and they sit on a perfectly flat horizontal bed of limestone. This design deliberately mimics the ceiling chambers.

Referring back to Diagram B4 which shows the missing floor stones in the chamber, the only value that has been taken into account so far is the distance *n* from the top of the chamber's granite floor to the base line of the walls, and not the thickness of the rest of the floor which is shown by the letter *d* on the diagram and is around 5.5 inches in depth, or 0.26 cubits.

If all of the unfolded walls of the upper chamber are dropped down so that the gap between them and the top of the lower chamber walls is exactly 2n cubits in height, with the sole purpose of making the logic of the system work, then the distance by which the walls need to drop must be the surveyed gap height of 0.673 cubits less 2 x 0.2076, or by a distance of 0.258 cubits - the same as the value of the unused floor depth *d* in the upper chamber.

The walls of the upper chamber can therefore be unfolded using the *underside* of the upper chamber floor as the primary horizontal reference line, and when this is performed the gap between the unfolded upper chamber and the top of the lower chamber walls is precisely 2*n* by design. In so doing, the distance *d* is moved up to the top of the upper chamber as shown by the dotted line just below the chamber roof on Diagram B7.

The value of *d* should still be regarded as an unknown quantity with the difference being that it is now at the top of the upper chamber rather than at the bottom, and the two stack systems of the lower and upper chambers have been combined into one logical continuous stack.

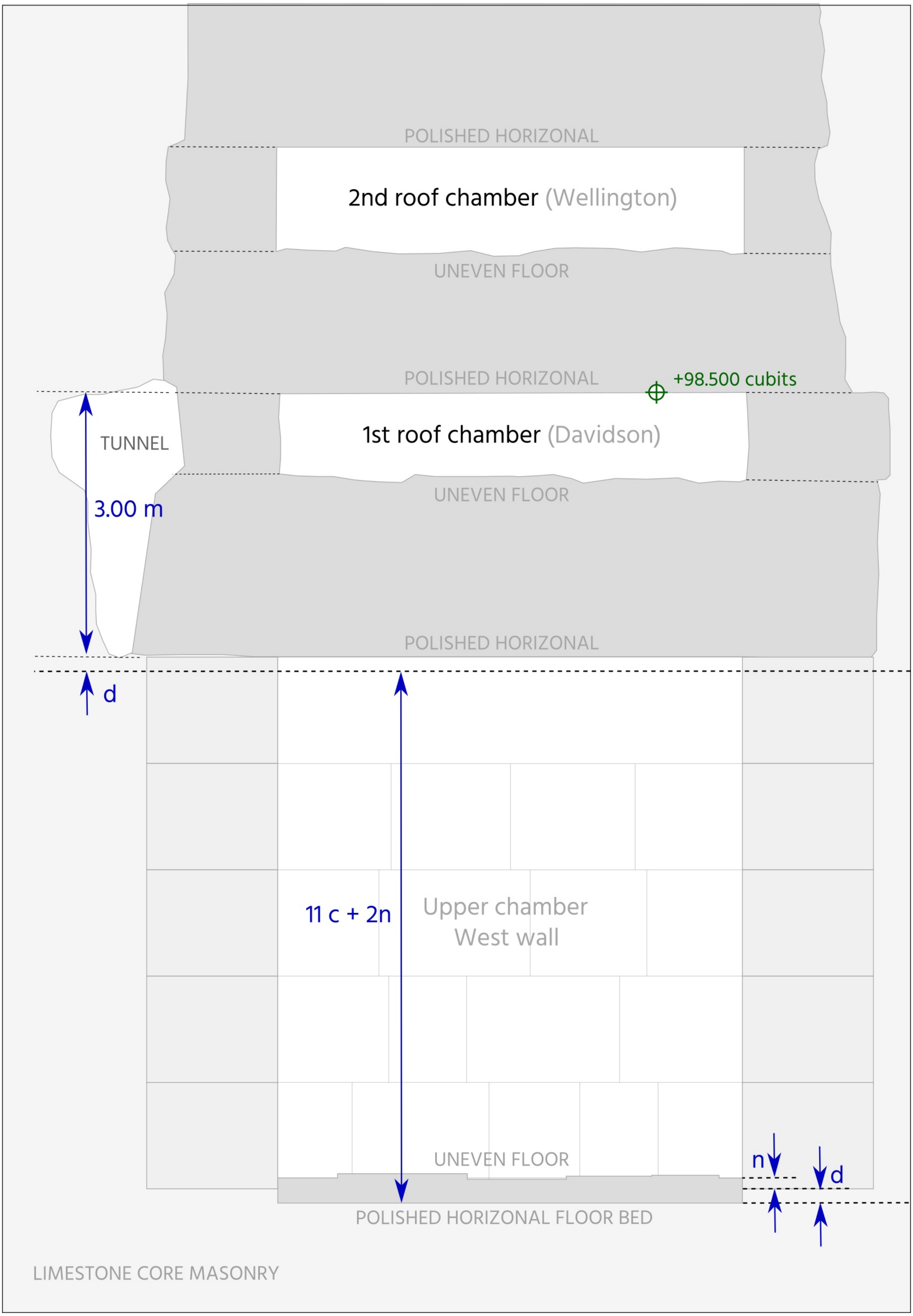

Diagram B7 - The first releiving chamber relative to the main chamber

The distance from the roof chamber that is above the upper chamber was accurately measured[9] due to a original architect's tunnel section that is carved out of the core masonry between the roof chamber and the upper chamber, also shown on Diagram B7. The distance *d* that has been moved to the top of the upper chamber therefore combines with the 3.00m tunnel into one unified unknown quantity.

The top of the upper chamber is designed with this unified value so that it can be seen that it is the altitude of the ceiling of the first roof chamber that is important in the design, and not the altitude of the upper chamber roof. The altitude of the first roof chamber's ceiling can be determined from the corrected surveying measurements of Petrie and Maragioglio and Rinaldi[9] as follows :

Chamber roof to relieving roof	+ 118.11 " (3.00m)	M&R
Height of upper chamber walls	+ 235.20 "	Petrie
Base of upper chamber walls	+ 1688.50 " above ground level	Petrie
Vertical error adjustment	- 12.32" (31.3cm)	Brabin[1]

giving the altitude of the first roof chamber's ceiling as 98.50 cubits (2029.49"). Therefore the full height of the chamber stack up to this ceiling level from the 11.00 cubit altitude raised ground below the center of the pyramid is 87.50 cubits.

(It should be noted at this point that the tunnel section which allows the 3.00m vertical distance to be measured is the only known surveying measurement of the roof chamber's position relative to the rest of the internal architecture of the building, and the supposition that the relieving chambers are directly above the upper chamber has no supporting surveying information. The horizontal location of the first roof chamber is unknown and the vertical location is known with high accuracy.)

Resolving the unknown distances

If you review the combined upper and lower chamber stacks from bottom to top, there are two incomplete values which are only known from surveying measurements. The first is the height of the lower chamber walls of 4.685m (184.47") and the second is the distance from the top of the upper chamber dotted roof line on diagram B7 to the ceiling of the 1st roof chamber, a distance of 0.26 cubits + 3.00 meters.

After analysis, these two distances can be resolved using just the information presented in the architecture, namely the full stack height of 87.5 cubits and the stack constant length *n*.

The unknown distance in the upper chamber

$$87.5\,n / 3 \text{ cubits} = 5.96 \text{ cubits} = 3.122 \text{ meters}$$

The lower chamber wall height is

$$87.5n / 2 \text{ cubits} = 8.95 \text{ cubits} = 4.684 \text{ meters}$$

The full stack

The stack is now complete from the ground level to the ceiling of the 1st roof chamber, with all distances expressed in either cubits or the stack constant unit *n*, and the total height of the stack is known to be 87.5 cubits. It must therefore be possible to solve the value of *n* in terms of the cubit and thereby define its exact length. Diagram B8 shows the full chamber stack with all the known distances marked.

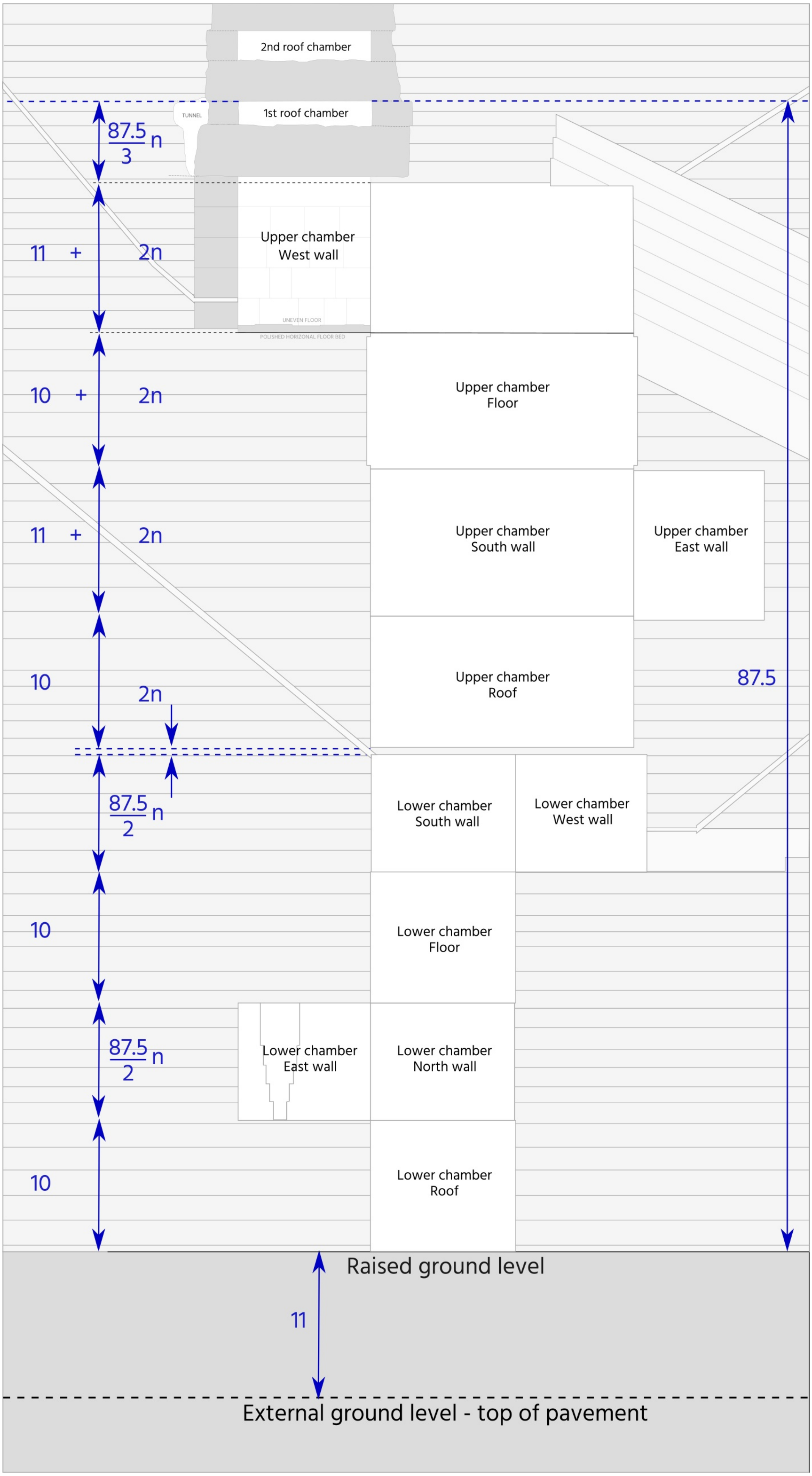

Diagram B8 - The full chamber stack

The stack equation is solved as follows:

$$62 \text{ cubits} + 8n + \frac{2 \times 87.5n}{2} + \frac{87.5n}{3} = 87.5 \text{ cubits}$$

$$\Rightarrow \quad \frac{24n + 262.5n + 87.5n}{3} = 25.5 \text{ cubits}$$

$$\Rightarrow \quad n = \frac{153}{748} \text{ cubits}$$

This precise value of the stack constant of 153/748 cubits allows all of the component parts of the chamber stack to be individually positioned within the building without the need to refer to any surveying measurements. The fraction 153/748 expressed in decimal format is 0.20454545.

Reference points within the stack

The following list shows the architecture reference points within the chamber stack relative to ground level, that being Petrie's surveying level at the top of the pavement outside the pyramid.

Level (cubits)	Description	
98.5000	Roof of 1st relieving chamber	
92.5341	Virtual roof line, upper chamber	
81.1250	Floor bed, upper chamber	Note : exactly 81 + 1/8 cubits
51.8728	Apex of lower chamber roof	
48.8977	Top of lower chamber walls	
39.9489	Floor of lower chamber	
11.0000	Raised ground level	
0	Petrie's ground level (top of pavement)	

What is of particular note in this list, taking into account how the measurements are constructed from the ground level upwards, is that the upper chamber floor bed is exactly 81 + 1/8 cubits in elevation above ground level. In mathematical terms

$$62 + (87.5 + 6) \times (153/748) = 81 + (1/8)$$

This is a very tidy piece of mathematics and as it specifies the reference level of what has to be considered as the main chamber of the pyramid, it confirms that the original design has been correctly determined and the fraction 153/748 is the correct value for the stack constant.

Supplementary reference points within the stack

The following supplementary list of *surveyed* reference points is dependent upon surveying distances which cannot be resolved into stack constant values, by design. The purpose of these levels is to show that each of these particular features is irrelevant to the vertical design of the building.

92.767	Roof of upper chamber
81.563	Top of floor in S.E. corner, upper chamber
81.358	Base of walls, upper chamber

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