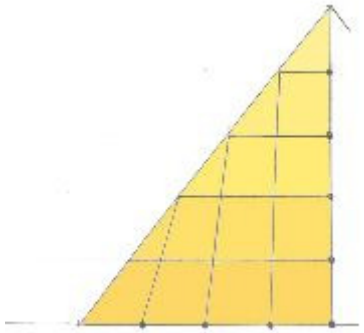
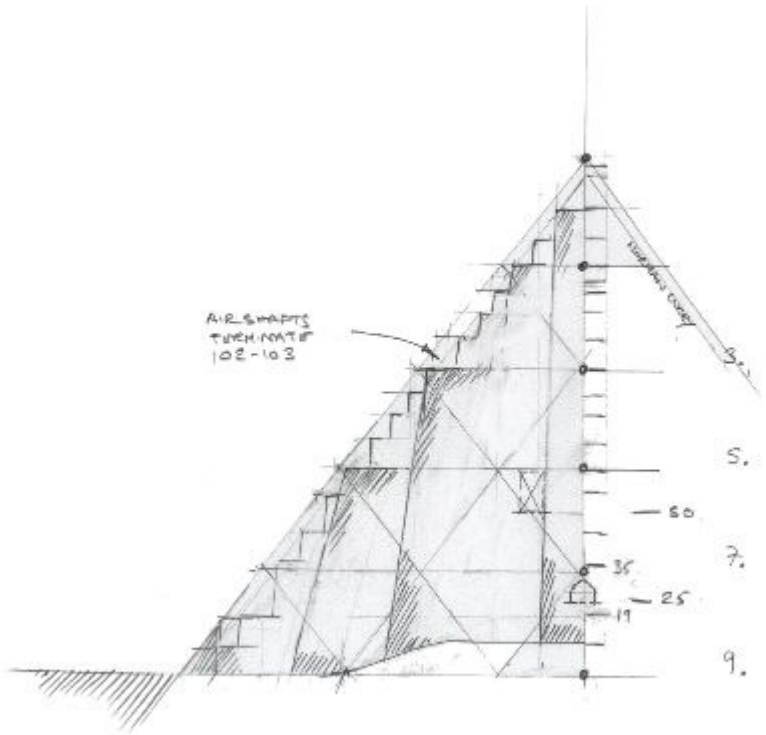


HYPOTHESIS

The construction of the 'Great Pyramid'. A mystery for centuries; how was it done? A Construction Hypothesis by Norman Lucey.

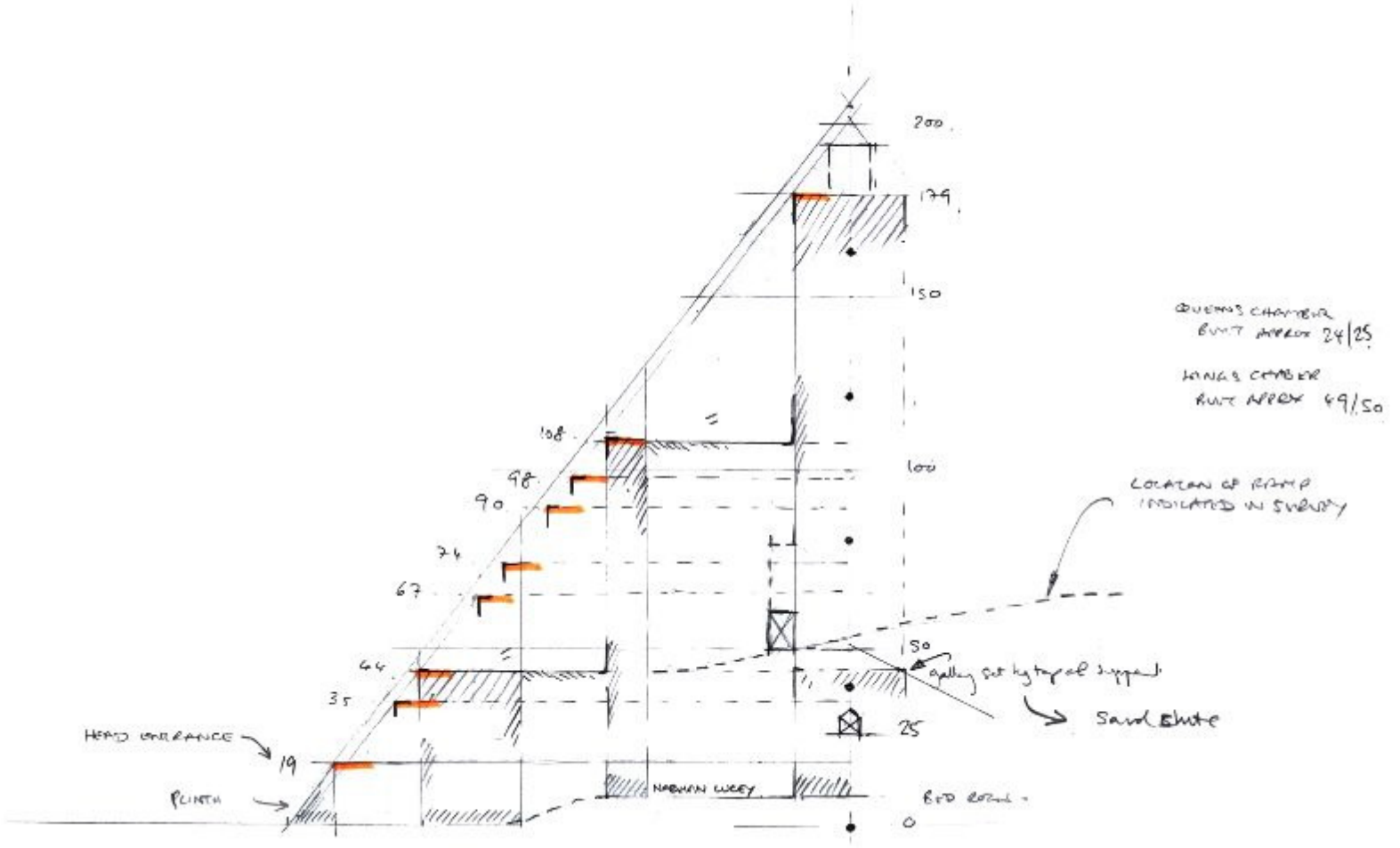
Base levelling and establishing and maintaining centre point

It is generally accepted that the perimeter was levelled using a water trough set out in the basalt pavement around the perimeter. The building was carefully oriented to north using a shadow rod (gnoman) and squared with ropes, leaving the rock outcrop raised up within the central area, rough levelled to take the stones. The three pyramids on the Giza plateau are arranged to avoid overshadowing. Each corner was carefully marked with a large limestone corner stone, set in a floor socket and establishing, for all time, the angles of the faces and anticipated apex approx. 200 courses above. The critical part of the exercise was the permanent establishment of the centre point which would be transferred up the building as it progressed. With sand-storms and over the years this point would need to be indelibly carved in stonework on a central tower constructed in the most careful manner.



Establishing working platforms/terraces and access to them

It appears from the survey evidence available that from the beginning, three significant working platforms were proposed, located at heights approx. an eighth, a quarter and half way up the pyramid; the retaining walls getting progressively thicker towards the bottom, taking account of the mass of material they would retain. A central masonry core tower continued through this structure, possibly battered externally or stepped to permanently record working heights and the central position, as the building progressed. This is the reason all the internal chambers and galleries are offset from the centre.



Retaining walls and rubble infill

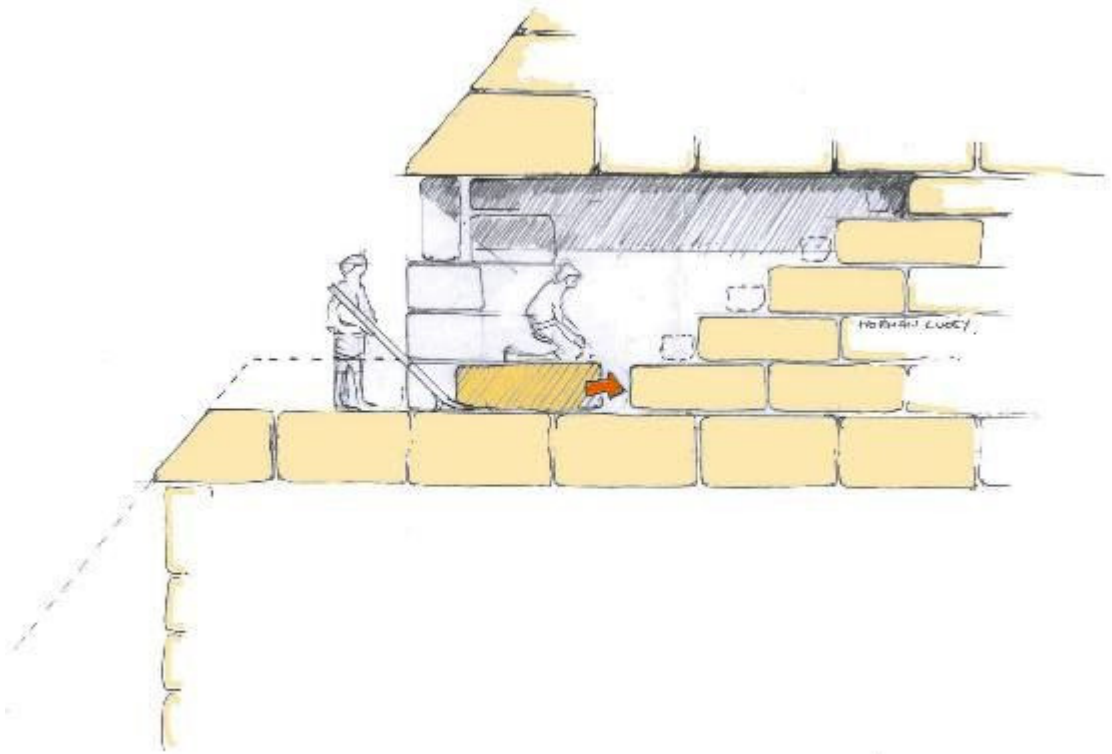
As these masonry retaining walls were constructed in a similar manner to the mastaba, ramps supported from within the profile of the structure were progressed and the volume to the rear of these walls filled with rubble and sand.

Locations of terraces and sorting stonework

It is proposed that the locations of these terraces can be established from the positions of the solid internal retaining walls and the range of stonework thicknesses exhibited in the backing stones now visible on the outside, after the removal of the limestone casing. Great care was taken to select stones in progressively reduced thickness as they were taken from the adjacent quarry seams. Each course was progressively reduced in size, driven by the criteria that only smaller stones should be placed on top of larger more stable ones and making them easier to raise and install above the working platform. The tops of these stones were trimmed if necessary to receive the next course. These progressions in the stone courses originally surveyed by Petrie, clearly identify the primary terraces and the intermediate ones created as working platforms.

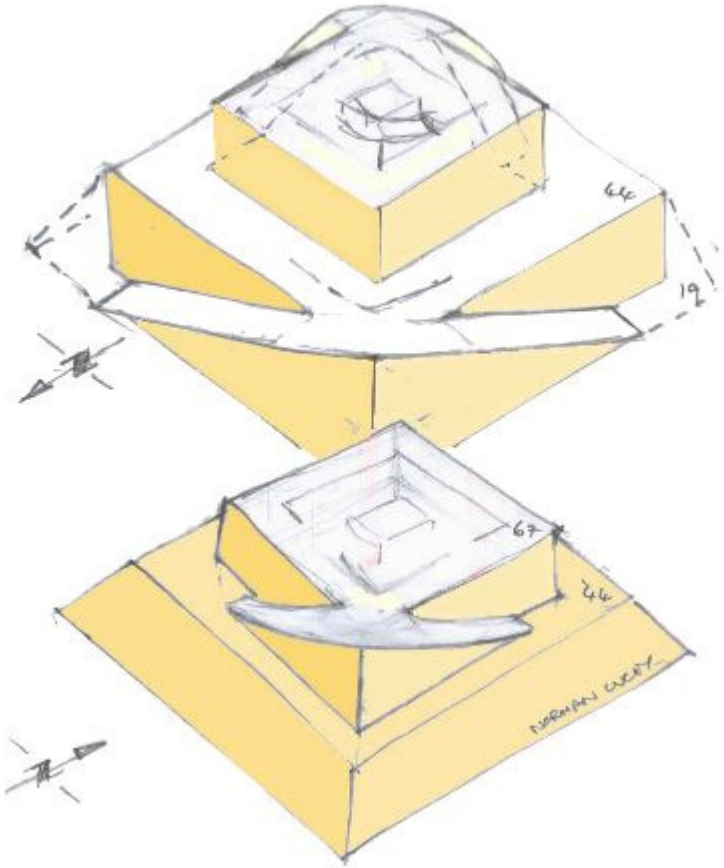
Terrace edges maintain external lines and levels

In order to maintain and control the batter or rake of all four sides, the edges of each significant terrace would be completed with an edging of raked control stones positioned in relation to the fixed centre point. This could only be done on a level platform within the retaining walls. Once these were set out, then further terraces could be created above and intermediate working platforms around the perimeter at intermediate levels between them. This established greater control over the setting out of the building and avoided the possibility of cumulative errors through progressive construction. There is evidence that the building was also set out from the middle of each side as it actually has eight faces not four. This was important to maintain that all faces coincided at the same apex and did not create a ridge configuration at the top. The only satisfactory method of making certain the sides of the pyramid remained flush from top to bottom was to install a central strip of thicker guide stones from top to bottom on each side with access ways beneath to maintain a route around the terraces, prior to commencing the rest of the work. The silhouette of the building also indicates the locations of these terraces.



Positions of ramps for access both up and down

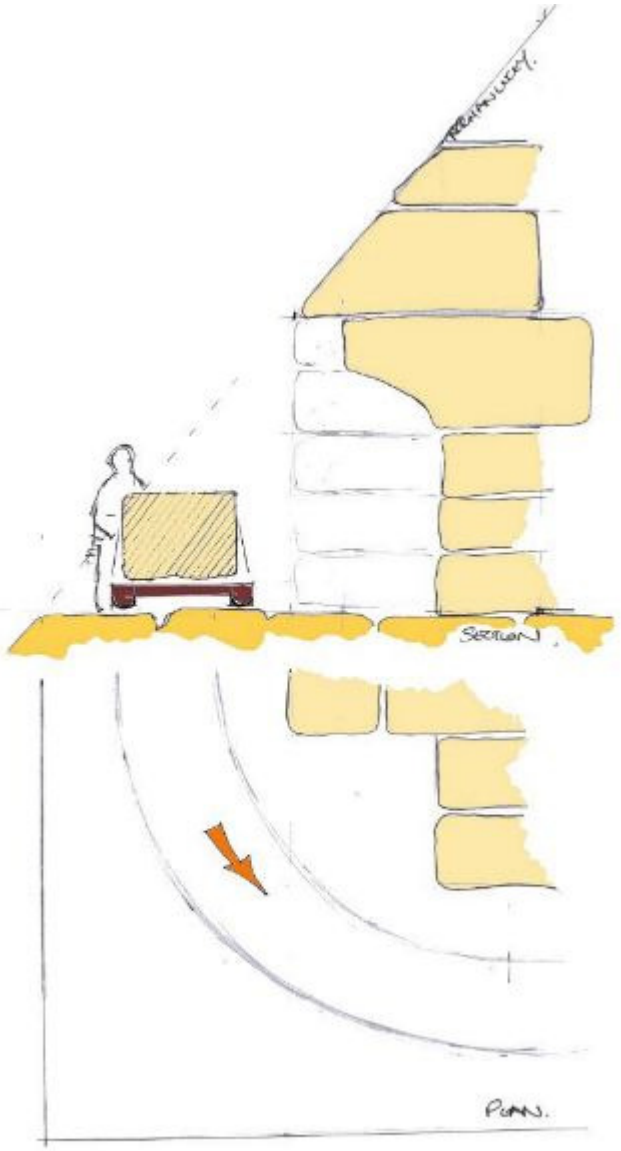
All large stones would be slid into position using timber sledges and levers. The lack of timber and its import from Lebanon meant that it was a valuable resource. Arrangements would be put in place to allow materials and workers to move both up and down the structure systematically. Survey evidence has suggested the locations of ramps between the significant terraces. They were built within the overall structure of the build to avoid abortive work and filled in progressively as the building was finished downwards from the top. The positions of ramp support masonry can be seen in the survey with loose fill to the raked ramp surface and to terraces above and below. This also provides evidence of the ramp gradients used and their suitability for sledges pulled by teams of oxen.



Use of compacted sand decks to move and position stones

Due to the lack of timber it was essential that working platforms were created only from the work as it progressed. Stonework could only be slid into position from the interior of the building and carefully positioned against the previous stone. To reduce the amount of redundant material hauled up the building, all facing stones would be raked in the quarry and once on the working terrace sawn in conjunction with its neighbour with copper saws, before being levered into position at the perimeter from the working platform to the side and rear. Levers would move the stone back and forth until it was in line with the course below. Mortars were used on the casing joints to seal them from the weather. It would be natural for the facing stones to

be fitted together on the deck where there was working room before locating it on the precipice. Backing stones, carefully selected for thickness would then back up these facing stones and be covered with sand to provide a new flush working top surface for sliding the next stones. These backing stones are all that can be seen today and the sand has been consequently lost. As stones have to be manoeuvred around the terrace corners, the walls of these terraces are set back at this point. This can be seen in the exiting notch on the NE corner and at the top. Originally known by the arabs as the half-way point on the ascent.


SECTION
PLAN.

Issues with settlement (Kings Chamber)

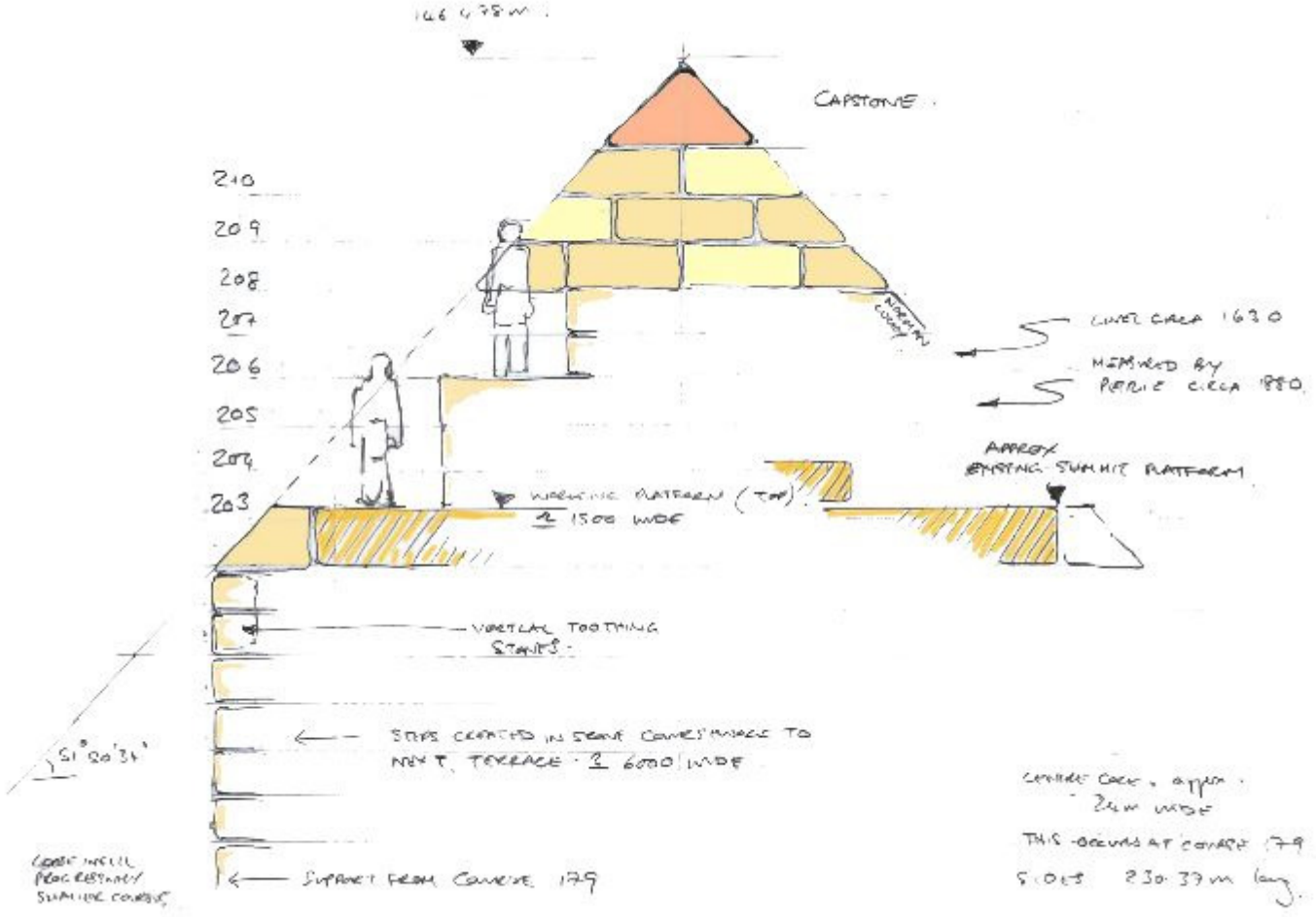
There were obviously considerable problems with settlement of the fill when constructing the Kings Chamber. So much so that granite slabs were piled up to several layers above to weigh down the walls and bring the chamber to a stable position. Unfortunately this settlement was not consistent due to the rigidity of the central core stonework and this is evident in the cracked exposed soffit slabs and Petrie's survey of distortion in the wall slabs. The floor slabs in both chambers were installed separately between the walls to take account of this settlement and provide suitable tolerance.

Removal of sand from chambers - shutters and sand chute

Egyptian engineering relied on the use of sand to transport and position stonework, either horizontally or vertically (as used for the obelisks and raking roof and entrance slabs). To achieve this, internal chambers would have been filled with sand to allow the positioning of stonework above. All internal stonework had to be tight and filled with plaster to prevent the ingress of sand from above as construction continued, particularly above the King's Chamber. This sand could be dangerous and bury workers alive. It had to be compacted and controlled, hence the use of shutters at the chamber entrance to hold back the sand and allow it be removed in a controlled fashion. This is why the top of the Grand Gallery has a vee shaped stone to feed this sand into the chute that would take it out of the building. During construction there was always the possibility of sand entering these areas by accident or from storms. It had to be controlled and removed in a controlled fashion. The well shaft may have been a method of doing this as it is not vertical and would be more suitable as a chute rather than for lifting water.

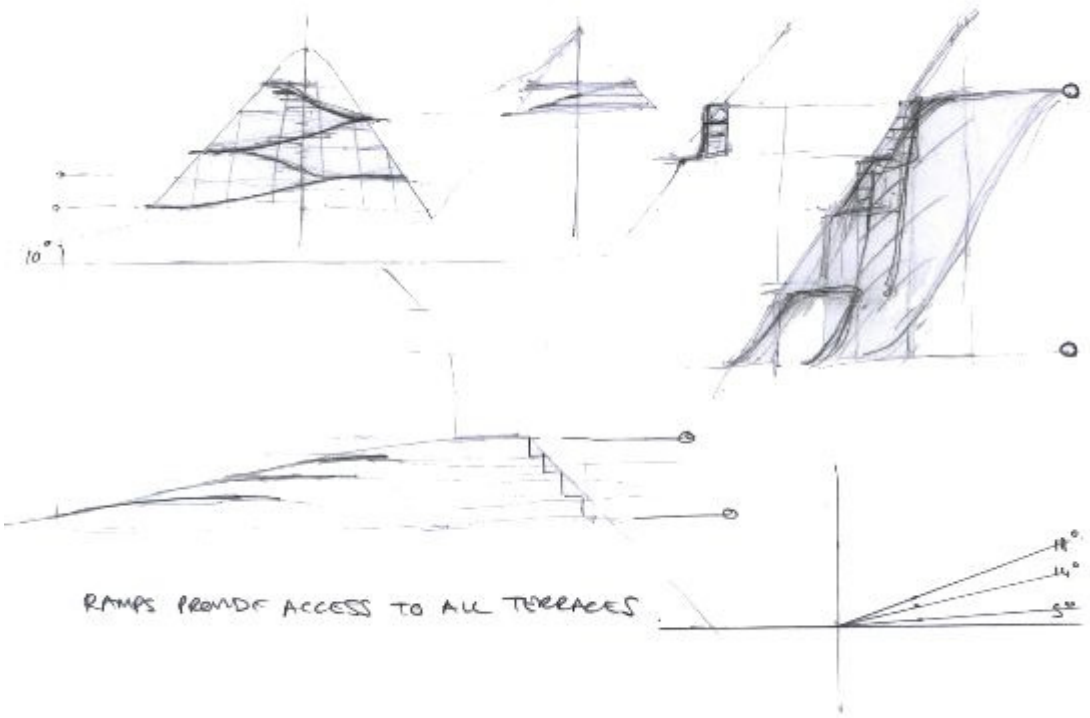
Working platforms and steps to fix capstone

The positioning of the capstone or pyramidion directly over the centre point, carefully plumbed up from its position below, stone by stone, was obviously an event and celebration. Access to this perilous position would have been created using working platforms supported from the terraced stonework below and with stone steps cut in between these platforms. The capstone would have been levered up, wedged, blocked and raised to it's correct height above the top and final working platform and after the celebrations, battered limestone casing stones fitted below. Great care would have been necessary to avoid the loss of this valuable capstone over the edge and space would have been necessary around it for dignitaries. It is suggested that all this is done using support from the structure itself and not from dangerous secondary timber platforms. The top platform was probably made larger for this purpose. Once the capstone was laid on finished raked limestone facing stones, the finishing of the building would progress downwards as described by Herodotus Access steps and ramps would be progressively filled in and lost. Access would no longer be possible to the top.



Infilling ramps and facing terraces, toothing in and progressing down

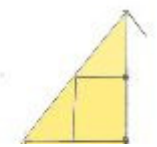
To allow stonework to be fitted to the terraces and working platforms as they were built out and the work progressed downwards, there is evidence of vertical stones, left to support the casing to allow other later stones to be toothed in below. Due to the tolerance in fitting this work to the already finished stonework above, progressively thinner stones were used to allow them to be raised and levered up on blocks by hand and slipped into position into the tapered space. Final finishing of the facing stones in completed areas was undertaken by scaling ladder from the terrace below.



Final finishing and facing stonework

Herodotus states in book two of his "Histories" that "the pyramid itself was twenty years in the making" and that "the whole is of stone polished and most exactly fitted". The limestone facing stones are relatively easy to work, especially when fresh and not case hardened. Tourists to the top confirmed how easy it was to carve graffiti in these stones and evidence of sand erosion at the base and to the capping of the adjacent pyramid is clear. Hence the reason later pyramids used granite for the plinth stones.

A large amount has been written about the angles and dimensions within the pyramid. My own suggestion is that the internal passageways have been arranged at a gradient of 1 in 2 and the pyramid at a batter of 5 in 4; all set out using their simple tools of 'A frame' and plumb bob, sighted with a merket. The outer wall of the internal mastaba arranged at the traditional 4 in 1.



Interested / critical ?

contact me and let me know at.....

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