The Pyramids and Temples of Gizeh ... 1883.

SIR W.M.FlINDERS PETRIE. source

Notes ... a short introduction to the site.
Measure ... summary of the Great Pyramid's more important measures.
Illustrations ... from the back of the book.

CHAPTERS 1 - 7.

1. The nature of the present work is such that perhaps few students will find interest in each part of it alike. The ends and the means appeal to separate classes: the antiquarian, whose are the ends, will look askance at the means, involving co-ordinates, probable errors, and arguments based on purely mechanical considerations; the surveyor and geodetist, whose are the means, will scarcely care for their application to such remote times; the practical man who may follow the instrumental details, may consider the discussion of historical problems to be outside his province ; while only those familiar with mechanical work will fully realize the questions of workmanship and tools here explained.

An investigation thus based on such different subjects is not only at a disadvantage in its reception, but also in its production. And if in one part or another, specialists may object to some result or suggestion, the plea must be the difficulty of making certain how much is known, and what is believed, on subjects so far apart and so much debated.

The combination of two apparently distinct subjects, is often most fertile in results ; and the mathematical and mechanical study of antiquities promises a full measure of success. It is sometimes said, or supposed, that it must be useless to apply accuracy to remains which are inaccurate; that fallacies are sure to result, and that the products of such a method rather originate with the modern investigator than express the design of the ancient constructor. But when we look to other branches of historical inquiry, we see how the most refined methods of research are eagerly followed : how philology does not confine itself to the philological ideas of the ancient writers, but analyzes their speech so as to see facts of which they were wholly unconscious; how chemistry does not study the chemical ideas, but the chemical processes and products of the ancients; how anthropology examines the bodies and customs of men to whom such inquiries were completely foreign. Hence there is nothing unprecedented, and nothing impracticable, in applying mathematical methods in the study of mechanical remains of ancient times, since the object is to get behind the workers, and to see not only their work, but their mistakes, their amounts of error, the limits of their ideas; in fine, to skirt the borders of their knowledge and abilities, so as to find their range by means of using more comprehensive methods. Modern inquiry should never rest content with saying that anything was "exact;" but always show what error in fact or in work was tolerated by the ancient worker, and was considered by him as his allowable error.

2. The materials of the present volume have been selected from the results of two winters' work in Egypt. Many of the points that were examined, and some questions that occupied a considerable share of the time, have not been touched on here, as this account is limited to the buildings of the fourth dynasty at Gizeh, with such examples of later remains as were necessary for the discussion of the subject. All the inscriptions copied were sent over to Dr. Birch, who has published some in full, and extracted what seemed of interest in others; Dr. Weidemann has also had some of them; and they do not need, therefore, further attention on my part. Papers on other subjects, including the Domestic Remains, Brickwork, Pottery, and travellers' graffiti. each of which were examined with special reference to their periods, are in course of publication by the Royal Archaeological Institute. The mechanical methods and tools employed by the Egyptians were discussed at the Anthropological Institute, and are more summarily noticed here. A large mass of accurate measurements of remains of various ages were collected ; and these, when examined, will probably yield many examples of the cubits employed by the constructors. Of photographs, over five hundred were taken, on 1/4 size dry plates, mainly of architectural points, and to show typical features. Volumes of prints of these may be examined on application to me, and copies can be ordered from a London photographer. The lesser subjects being thus disposed of; this volume only treats of one place, and that only during one period, which was the main object of research. The mass of the actual numerical observations and reductions would be too bulky to publish, and also unnecessary; the details of the processes are, in fact, only given so far as may prove useful for comparison with the results obtained by other observers.

Though, in describing various features, reference has often been made to the publications of Colonel Howard Vyse * (for whom Mr. Perring, C.E., acted as superintendent), and of Professor C. Piazzi Smyth ** yet it must not be supposed that this account professes at all to cover the same ground, and to give all the details that are to be found in those works. They are only referred to where necessary to connect or to explain particular points; and those volumes must be consulted by any one wishing to fully comprehend all that is known of the Pyramids.

* " Operations at the Pyramids ", 3 vols, 1840. ** " Life and Work at the Great Pyramid ", 3 vols. 1867.

This work is, in fact, only supplementary to the previous descriptions, as giving fuller and more accurate information about the principal parts of the Pyramids, with just as much general account as may be necessary to make it intelligible, and to enable the reader to judge of the discussions and conclusions arrived at on the subject, without needing to refer to other works. Colonel Vyse's volumes are most required for an account of the arrangements of the Second and smaller Pyramids, of the chambers in the Great Pyramid over the King's Chamber, of the negative results of excavations in the masonry, and of various mechanical details. Professor Smyth's vol. ii. is required for the measurements and description of the interior of the Great Pyramid. While the scope of the present account includes the more exact measurement of the whole of the Great Pyramid, of the outsides and chambers of the Second and Third Pyramids, of the Granite Temple, and of various lesser works; also the comparison of the details of some of the later Pyramids with those at Gizeh, and various conclusions, mainly based on mechanical grounds.

The reader's knowledge of the general popular information on the subject, has been taken for granted ; as that the Pyramids of Gizeh belong to the first three kings of the fourth dynasty, called Khufu, Khafra, and Menkaura, by themselves, and Cheops, Chephren, and Mycerinus; by Greek-loving Englishmen; that their epoch is variously stated by chronologers as being in the third, fourth, or fifth millennium BC.; that the buildings are in their bulk composed of blocks of limestone, such as is found in the neighbouring districts; that the granite used in parts of the insides and outsides was brought from Syene, now Assouan; and that the buildings were erected near the edge of the limestone desert, bordering the west side of the Nile valley, about 150 feet above the inundated plain, and about 8 miles from the modern Cairo.

3. One or two technical usages should be defined here. All measures stated in this volume are in Imperial British inches, unless expressed otherwise; and it has not been thought necessary to repeat this every time an amount is stated ; so that in all such cases inches must be understood as the medium of description. Azimuths, wherever stated, are written + or --, referring to positive or negative rotation, i.e., to E. or to W., from the North point as zero. Thus, azimuth -- 5', which often occurs, means 5' west of north. Where the deviation of a line running east and west is stated to be only a few minutes + or --, it, of course, refers to its normal or perpendicular, as being that amount from true north.

The probable error of all important measurements is stated with the sign ± prefixed to it as usual. A full description of this will be found in any modern treatise on probabilities; and a brief account of it was given in "Inductive Metrology," pp.24 - 30. Some technical details about it will be found here in the Appendix on "The Rejection of Erroneous Observations" ; and I will only add a short definition of it as follows :--- The probable error is an amount on each side of the stated mean, within the limits of which there is as much chance of the truth lying, as beyond it; i.e., it is 1 in 2 that the true result is not further from the stated mean than the amount of the probable error. Or, if any one prefers to regard the limits beyond which it is practically impossible for the true result to be, it is 22 to 1 against the truth being 3 times the amount of the probable error from the mean, 144 to 1 against its being 4 times, or 1,380 to 1 against its being as far as 5 times the amount of the probable error from the mean result stated. Thus, any extent of improbability that any one may choose to regard as practical impossibility, they may select; and remember that 4 or 5 times the probable error will mean to them the limit of possibility. Practically, it is best to state it as it always is stated, as the amount of variation which there is an equal chance of the truth exceeding or not; and any one can then consider what improbability there is in any case on hand, of the truth differing from the statement to any given extent.

It should be mentioned that the plans are all photo lithographed from my drawings, in order to avoid inaccuracy or errors of copying; and thence comes any lack of technical style observable in the lettering.

As to the results of the whole investigation, perhaps many theorists will agree with an American, who was a warm believer in Pyramid theories when he came to Gizeh. I had the pleasure of his company there for a couple of days, and at our last meal together he said to me in a saddened tone, ---" Well, sir ! I feel as if I had been to a funeral." By all means let the old theories have a decent burial; though we should take care that in our haste none of the wounded ones are buried alive.

4. The small piece of desert plateau opposite the village of Gizeh, though less than a mile across, may well claim to be the most remarkable piece of ground in the world.
There may be seen the very beginning of architecture, the most enormous piles of building ever raised, the most accurate constructions known, the finest masonry, and the employment of the most ingenious tools; whilst among all the sculpture that we know, the largest figure---the Sphinx---and also the finest example of technical skill with artistic expression---the Statue of Khafra---both belong to Gizeh. We shall look in vain for a more wonderful assemblage than the vast masses of the Pyramids, the ruddy wall and pillars of the granite temple, the titanic head of the Sphinx, the hundreds of tombs, and the shattered outlines of causeways, pavements, and walls, that cover this earliest field of man's labours.

But these remains have an additional, though passing, interest in the present day, owing to the many attempts that have been made to theorise on the motives of their origin and construction. The Great Pyramid has lent its name as a sort of by-word for paradoxes; and, as moths to a candle, so are theorisers attracted to it. The very fact that the subject was so generally familiar, and yet so little was accurately known about it, made it the more enticing; there were plenty of descriptions from which to choose, and yet most of them were so hazy that their support could be claimed for many varying theories.

Here, then, was a field which called for the resources of the present time for its due investigation ; a field in which measurement and research were greatly needed, and have now been largely rewarded by the disclosures of the skill of the ancients, and the mistakes of the moderns. The labours of the French Expedition, of Colonel Howard Vyse, of the Prussian Expedition, and of Professor Smyth, in this field are so well known that it is unnecessary to refer to them, except to explain how it happens that any further work was still needed. Though the French were active explorers, they were far from realising the accuracy of ancient work ; and they had no idea of testing the errors of the ancients by outdoing them in precision. Hence they rather explored than investigated. Col. Vyse's work, carried on by Mr. Perring, was of the same nature, and no accurate measurement or triangulation was attempted by these energetic blasters and borers; their discoveries were most valuable, but their researches were always of a rough-and-ready character. The Prussian Expedition sought with ardour for inscriptions, but did not advance our knowledge of technical skill, work, or accuracy, though we owe to it the best topographical map of Gizeh. When Professor Smyth went to Gizeh he introduced different and scientific methods of inquiry in his extensive measurements, afterwards receiving the gold medal of the Royal Society of Edinburgh in recognition of his labours. But he did not attempt the heaviest work of accurate triangulation. Mr. Waynman Dixon, C.E., followed in his steps, in taking further measurements of the inside of the Great Pyramid. Mr. Gill---now Astronomer Royal at the Cape---when engaged in Egypt in the Transit Expedition of 1874, made the next step, by beginning a survey of the Great Pyramid base, in true geodetic style. This far surpassed all previous work in its accuracy, and was a noble result of the three days' labour that he and Professor Watson were able to spare for it. When I was engaged in reducing this triangulation for Mr. Gill in 1879, he impressed on me the need of completing it if I could, by continuing it round the whole pyramid, as two of the corners were only just reached by it without any check.

When, after preparations extending over some years, I settled at Gizeh during 1880-2, I took with me, therefore, instruments of the fullest accuracy needed for the work; probably as fine as any private instruments of the kind. The triangulation was with these performed quite independently of previous work; it was of a larger extent, including the whole hill; and it comprised an abundance of checks. The necessary excavations were carried out to discover the fiducial points of the buildings, unseen for thousands of years. The measurements previously taken were nearly all checked, by repeating them with greater accuracy, and, in most cases, more frequency; and fresh and more refined methods of measurement were adopted. The tombs around the pyramids were all measured, where they had any regularity and were accessible. The methods of workmanship were investigated, and materials were found illustrating the tools employed and the modes of using them.

5. For a detailed statement of what was urgently wanted on these subjects, I cannot do better than quote from a paper by Professor Smyth,* entitled, "Of the Practical Work still necessary for the Recovery of the Great Pyramid's ancient, from its modern, dimensions"; and add marginal notes of what has now been accomplished.

* *Edinburgh Astronomical Observations, vol xiii,p.3*

"As my measures referred chiefly to the interior of the structure, and as there the original surfaces have not been much broken, the virtual restoration of that part has been by no means unsuccessful ; and requires merely in certain places---places which can only be recognised from time to time as the theory of the building shall advance---still more minutely exact measures than any which I was able to make, but which will be comparatively easy to a scientific man going there in future with that one special object formally in view."
Notes of work.1880-2 ... The whole interior now re-examined and much remeasured, more accurately.

"The exterior, however, of the Great building, is exceedingly dilapidated, and I have few or no measures of my own to set forth for its elucidation. That subject is, therefore, still "to let" ; and as it is too vast for any private individual to undertake at his own cost, I may as well explain here the state of the case, so that either Societies or Governments may see the propriety of their taking up the grand architectural and historical problem, and prosecuting it earnestly until a successful solution of all its parts shall have been arrived at."
Notes of work.1880-2 ... Total cost of present work £300.

"size and Shape, then, of the ancient exterior of the Great Pyramid, are the first desiderata to be determined."

(A statement of the various measurements of the base here follows.)

"As preparatory, then, to an efficient remeasurement of the length of the Base-sides of the Great Pyramid, itself an essential preliminary to almost all other Pyramidological researches, I beg to submit the following local particulars."
" (1.) The outer corners of four shallow sockets, cut in the levelled surface of the earth-fast rock outside the present dilapidated corners of the built Great Pyramid, are supposed to be the points to be measured between horizontally in order to obtain the original length of each external, finished, "casing-stone" base-side."
Notes of work.1880-2 ... Sockets are not corners of base-side.

" (2.) Previous to any such measurement being commenced, the present outer corners of those sockets must be reduced to their ancient corners, as the sockets have suffered, it is feared, much dilapidation and injury, even since 1865; owing to having been then imperfectly covered over, on leaving them, by the parties who at that time opened them."
Notes of work.1880-2 ... Sockets are apparently quite uninjured.

" (3.) The said sockets must be proved to have been the sockets originally holding the corner stones of the casing; or showing how far they overlapped, and therefore and thereby not defining the ancient base of the Great Pyramid to the amount so overlapped ... the ground should be cleared far and wide about each corner to see if there are any other sockets in the neighbourhood."
Notes of work.1880-2 ... By form of core, and by casing lines lying within the sockets, no others are possible.

"(4.) Whether any more rival sockets claiming to be the true corner sockets of the ancient base are, or are not, then and in that manner, found,---the usually known or selected ones should further be tested, by being compared with any other remaining indications of where the line of each base-side stood in former days. Some particular and most positive indications of this kind we know were found by Col. Howard Vyse in the middle of the Northern side; and there is no reason why as good markings should not be discovered, if properly looked for, along the other three sides; and they are so vitally important to a due understanding of the case, that their ascertainment should precede any expense being incurred on the measurement of lengths from socket to socket."
Notes of work.1880-2 ... Casing now found on all sides, and completely fixed.

"(5.) Col. H. Vyse found those invaluable markings of the line of the North base-side, or part of the very base-side itself, by accomplishing the heavy work of digging down by a cross cut, through the middle of the heap of rubbish, near 50 feet high, that side. But he has published no records of how those markings, or that actual portion of the

base-side, agree, either in level or in azimuth with the sockets. Indeed, he left the ground in such a state of hillock and hole, that no measures can, or ever will, be taken with creditable accuracy until a longitudinal cut through the rubbish heap shall be driven from East to West and all along between the two N.E. and N.W. sockets."
Notes of work.1880-2 ... Measures having been taken by triangulation no extensive cuttings were needed.

"(6.) The making of such a long and laborious cut, and then the "lining" and "levelling" of the bases of the Colonel's casing stones in situ (or their remains, for they are said to have been mischievously broken up since then), and their comparison with the sockets or their joining lines by appropriate and powerful surveying instruments, should be the first operation of the new measurers, to whom, it is fervently to be hoped, an intelligent Government will grant the due means for effecting it satisfactorily."
Notes of work.1880-2 ... Casing stones are not broken up, and the cutting is not necessary.

"(7.) A similar longitudinal cut, and similar comparisons are to be made in the other base-side hills of rubbish, together with a wider clearing away of the rubbish outside, in order to determine the form and proportion of the "pavement" which is believed to have anciently surrounded the Pyramid; but of which the only " positive information which we have, is based on the little bit of it which Col. H. Vyse cut down to near the middle of the North side."
Notes of work.1880-2 ... Sides now found by pits, and fixed by triangulation. Pavement traced on each side.

"This work might cost from £12,000 to £14,000; for the material to be cut through is not only extensive but so hard and a concreted that it turns and bends the hoes or picks employed in Nile cultivation, and which are the only tools the Arabs know of.
Notes of work.1880-2 ... Cuts, if wanted might be made for a tenth of this sum.

But besides the theoretical value of such an operation for distinguishing and identifying the base to be measured, it would certainly yield practically abundant fragments of casing stones, and perhaps settle the oft-mooted questions of ancient inscriptions on the outer surface of the Pyramid."
Notes of work.1880-2 ... Inscribed casing found, Greek.

"(8.) When the four sides of the base, and the corresponding sides of the pavement are exposed to view,---a new fixation of the exact original places of the precise outer corners of the now dilapidated and rather expanded corner sockets may be required ;
Notes of work.1880-2 ... Done.

and then, from and between such newly fixed points, there must be :-
A. Linear measures of distance taken with first-rate accuracy.
Notes of work.1880-2 ... Done.

B. Levellings.
Notes of work.1880-2 ... Done.

C. Horizontal angles, to test the squareness of the base.
Notes of work.1880-2 ... Done.

D. Astronomical measures to test the orientation of each of the base sides.
Notes of work.1880-2 ... Done.

E. Angular and linear measures combined to obtain both the vertical slope of the ancient Pyramid flanks, and the distance of certain of the present joints of the entrance passage from the ancient external surface of the Pyramid in the direction of that passage produced---a matter which is at present very doubtful, but a new and good determination of which is essential to utilize fully the numerous internal observations contained in this and other books."
Notes of work.1880-2 ... Done.

"(9.) When all the above works shall have been carefully accomplished, the men who have performed them will doubtless have become the most competent advisers as to what should be undertaken next; whether in search of the fourth chamber, concerning whose existence there is a growing feeling amongst those who have studied certain laws of area and cubic contents which prevail among the presently known chambers and passages; or for the more

exact measurement of certain portions of the building which shall then be recognised by the theory as of fiducial character and importance."
Notes of work.1880-2 ... Much of the interior now remeasured, with higher exactitude.

"(10.) Should the next remeasurement unfortunately not be under sufficiently favourable auspices or powerful patronage enough to attempt all that has been sketched out above---I would suggest to those employed upon it the importance of endeavouring to operate in that manner on at least the north side of the Great Pyramid alone, where much of the work has been already performed, and where traces of the old base-side are known to exist, or did certainly exist 34 years ago."
Notes of work.1880-2 ... All results obtained without patronage.

"(11.) The levels as well as temperatures of water in the wells of the plain close to the Pyramid, and in the Nile in the distance, should also be measured through a full twelve month interval. A meteorological journal should likewise be kept for the same period at the base of the Pyramid, and the corrections ascertained to reduce it either to the summit or King's chamber levels above, or to the plain level below; while no efforts should be spared to re-open the ventilating channels of the King's chamber and to prevent the Arabs from filling them up again."
Notes of work.1880-2 ... Channels filled by wind, not by Arabs.

"(12.) An examination should be made of the apparent Pyramid in the desert almost west of the Great Pyramid ; likewise of the northern coasts of Egypt, where they are cut by the Great Pyramid's several meridian and diagonal lines produced ;
Notes of work.1880-2 ... Done.

also of the fourth dynasty remains in the Sinaitic Peninsula ;
Notes of work.1880-2 ... N.W.Diagonal done.

and of any monuments whatever, whether in Egypt or the neighbouring countries for which any older date than that of the Great Pyramid can reasonably be assigned ;
Notes of work.1880-2 ... Done partly.

including also a fuller account than any yet published of King Shafre's Tomb and its bearings with, or upon, the origin, education, labours and life of the first of the Pyramid builders."
Notes of work.1880-2 ... Done.

6. To carry out, therefore, the work sketched in the above outline, and to investigate several collateral points, I settled at Gizeh in December, 1880, and lived there till the end of May, 1881 ; I returned thither in the middle of October that year, and (excepting two months up the Nile, and a fortnight elsewhere), lived on there till the end of April, 1882; thus spending nine months at Gizeh. Excellent accommodation was to be had in a rock-hewn tomb, or rather three tombs joined together, formerly used by Mr. Waynman Dixon, C.E.; his door and shutters I strengthened; and fitting up shelves and a hammock bedstead, I found the place as convenient as anything that could be wished. The tombs were sheltered from the strong and hot south-west winds, and preserved an admirably uniform temperature; not varying beyond 58° to 64° F. during the winter, and only reaching 80° during three days of hot wind, which was at 96° to 100° outside.

I was happy in having Ali Gabri,* the faithful servant of Prof. Smyth, Mr. Dixon, and Mr. Gill; his knowledge of all that has been done at Gizeh during his lifetime is invaluable; and his recollections begin with working at four years old, as a tiny basket carrier, for Howard Vyse in 1837. He was a greater help in measuring than many a European would have been; and the unmechanical Arab mind had, by intelligence and training, been raised in his case far above that of his neighbours. In out-door work where I needed two pair of hands, he helped me very effectually; but the domestic cares of my narrow Home rested on my own shoulders. The usual course of a day's work was much as follows :-- Lighting my petroleum stove, the kettle boiled up while I had my bath; then breakfast time was a reception hour, and as I sat with the tomb door open, men and children used to look in as they passed; often a friend would stop for a chat, while I hastily brewed some extra cups of coffee in his honour, on the little stove behind the door; Ali also generally came up, and sat doubled up in the doorway, as only an Arab can fold together.

* Called Ali Dobree by Prof. Smyth. G is universally pronounced hard by Egyptians, soft by Arabs ; thus either Gabri or Jabri, Gizeb or Jizeh, General or Jeneral, Gaz or Jaz (petroleum).

After this, starting out about nine o'clock, with Ali carrying part of the instruments, I went to work on the triangulation or measurements; if triangulating, it was Ali's business to hold an umbrella so as to shade the theodolite from the sun all day ---the observer took his chance ; if measuring, I generally did not require assistance, and worked alone, and I always had to get on as well as I could during Ali's dinner hour. At dusk I collected the things and packed up ; often the taking in of the triangulation signals was finished by moonlight, or in the dark. Then, when all was safely housed in my tomb, Ali was dismissed to his Home, and about six or seven o'clock I lit my stove, and sat down to reduce observations. Dinner then began when the kettle boiled, and was spun out over an hour or two, cooking and feeding going on together. Brown ship-biscuit, tinned soups, tomatoes (excellent in Egypt), tapioca, and chocolate, were found to be practically the most convenient and sustaining articles; after ten hours' work without food or drink, heavy food is not suitable ; and the great interruption of moving instruments, and breaking up work for a midday meal was not admissible. Then, after washing up the dishes (for Arab ideas of cleanliness cannot be trusted), I sat down again to reducing observations, writing, &c., till about midnight. Ali's slave, Muhammed the negro, and his nephew, little Muhammed, used to come up about nine o'clock, and settle in the next tomb to sleep as guards, safely locked in. Having a supply of candle provided for them, they solaced themselves with indescribable tunes on reed pipes; often joining in duets with Abdallah, the village guard, who used to come up for a musical evening before beginning his rounds. Very often the course of work was different; sometimes all out-door work was impossible, owing to densely sand-laden winds, which blew the grit into everything---eyes, nose, ears, mouth, pockets, and watches. During the excavations I turned out earlier---about sunrise; and after setting out the men's work, returned for breakfast later on in the morning. On other occasions, when working inside the Great Pyramid, I always began in the evening, after the travellers were clean away, and then went on till midnight, with Ali nodding, or even till eight o'clock next morning ; thus occasionally working twenty-four hours at a stretch, when particular opportunities presented themselves. The tomb I left furnished, as I inhabited it, in charge of Ali Gabri, and not having been looted in the late revolt, it will, I hope, be useful to any one wishing to carry on researches there, and applying to Dr. Grant Bey for permission to use the furniture.

7. My best thanks are due to M. Maspero, the Director of Antiquities , for the facilities he accorded to me in all the excavations I required, kindly permitting me to work under his firman; and also for information on many points. It is much to be hoped that the liberal and European policy he has introduced may flourish, and that it may overcome the old Oriental traditions and ways that clogged the Department of Antiquities. Excepting Arab help, I worked almost entirely single-handed ; but I had for a time the pleasure of the society of two artists: Mr. Arthur Melville, staying with me for a week in May, I881, and kindly helping in a preliminary measure of my survey base, and in an accurate levelling up to the Great Pyramid entrance; and Mr. Tristram Ellis, staying with me for a fortnight in March and April, 1882, and giving me most valuable help in points where accuracy was needed, laying aside the brush to recall his former skill with theodolite and measure. Thus working together, we measured the base of survey (reading to 100th of an inch) five times, in early dawn, to avoid the sunshine; we levelled up the Great Pyramid, and down again (reading to 100th of an inch) ; took the dip of the entrance passage to the bottom of it) and gauged its straightness throughout; took the azimuth of the ascending passages round Mamun's hole; callipered the sides of the coffer all over, at every 6 inches, and raised the coffer (weighing about 3 tons), by means of a couple of crowbars, to 8 inches above the floor, in order to measure the bottom of it. For the instrumental readings, in these cases, Mr. Ellis preferred, however, that I should be responsible, excepting where simultaneous readings were needed, as for the base length, and in Mamun's hole. To Mr. Ellis I am also indebted for the novel view of the Pyramids, showing the nine at once, which forms the frontispiece of this work.

To Dr. Grant Bey I owe much, both for occasional help at the Pyramid, in visiting the chambers of construction, the well, &c.; and also for his unvarying kindness both in health and sickness, realizing the conventional Arab phrase, "My house is thy house". Further, I should mention the kind interest and advice of General Stone Pasha, who gave me many hints from his intimate knowledge of the country; and also the very friendly assistance of our Vice-Consul, Mr. Raph. Borg, both in procuring an order for my residence and protection at Gizeh, and in prosecuting an inquiry into a serious robbery and assault on me, committed by the unruly soldiery in October, 1881 ; unhappily, this inquiry was a fruitless task apparently, as the military influence was too strong in the examination.

And now I must not forget my old friend Shekh Omar, of the Pyramid village, shrewd, sharp, and handsome; nor how anxious he was to impress on me that though some people of base and grovelling notions worked for money, and not for their "good name," he wished to work for fame alone; and as he had no doubt I should make a big book, he hoped that I should contract with him for excavations, and give him a good name. I gratified him with one

contract, but finding that it cost many times as much as hiring labourers directly; and was not sufficiently under control, the arrangement was not repeated; but I will say that I found him the most respectable man to deal with on the Pyramid hill, excepting, of course, my servant Ali Gabri, who was equally anxious about his good name, though too true a gentleman to talk much about it. The venerable Abu Talib and the loquacious Ibrahim, shekhs of the Pyramid guides, also conducted themselves properly, and Ibrahim seemed honestly genial and right-minded in his words and acts, and knew what so few Arabs do know---how not to obtrude. The rank and file of the guides---so familiar, with their little stocks of antikas in the corners of old red handkerchiefs---reckoned that I was free of the place, having Ali for my servant; they never gave me the least trouble, or even whispered the omnipresent word bakhshish but were as friendly as possible on all occasions, many claiming a hand-shaking and a hearty greeting. My impression of a year's sojourn with Arabs is favourable to them; only it is necessary to keep the upper hand, to resist imposition with unwearied patience, to be fair, and occasionally liberal in dealings, and to put aside Western reserve, and treat them with the same familiarity to which they are accustomed between different classes. With such intercourse I have found them a cheerful, warm-hearted, and confiding people.

8. The list of instruments employed was as follows:

A*	Standard scale, steel	100 inches long, divided to 1 inch.
b*	Steel tape	1,200 inches long, divided to 50 inch.
C	Steel chain	1,000 inches long, divided to 20 inch.
D	Pine poles, a pair 1 inch diam	140 inches long, divided to 10 inch.
E*	Pine rods, a pair 1 x 2 inches	100 inches long, divided to 1 inch.
F*	Pine rods, 10 of 1/2 x 1 inches	60 inches long, divided to 1 inch.
	(joining together into two lengths of)	250 inches each.
G*	Pine rods for levelling 3 of 1/2 x 2 inches	60 inches long, divided to 1 inch.
	Pine rods for levelling 2 of 1/2 x 1 inches	60 inches long, divided to 1 inch.
H*	Pine rods, 2 of 1/2 x 1 inches	20/40 inches long, divided to 1 inch.
J	Box of mahogany rods, 2 of 1 x 1	25 inches long, divided to 1/10 inch.
K	Boxwood scale 1.25 x .13	12 inches long, divided to 1/50 inch.
L	Steel scale, 1.07 x .04	12 inches long, divided to 1/10 inch.
M*	Ivory scales, 2 of 1.18 x .08	10 inches long, divided to 1/50 inch.
N*	Boxwood scale, 1.18 x .08	10 inches long, divided to 1/50 inch.
O*	Gun metal scale, 1.06 x .09	6 inches long, divided to 1/50 inch.
P*	Ivory scale, 1.0 x .08	1 inches long, divided to 1/100 inch.
	The divisions of those marked * are all known to within 1/1000 inch	
Q	Double calipers 72 inches long	
R	Supports for catenary measurement by tape and chain	
S	10 thermometers for scale temperatures	
a	Theodolite by Gambay 10 inch circle, divisions 5', vernier 3"	telescope x 35
	Theodolite by Gambay 7 inch circle, divisions 10', vernier 10"	
b	Theodolite by King 5 inch circle, divisions 30', vernier 1'	telescope x 6
	Theodolite by King 5 inch semicircle, divisions 30', vernier 1'	
c	Theodolite by Troughton 4 inch circle, 30', vernier 1'	telescope x 8
	Theodolite by Troughton 4 inch semicircle, 30', vernier 1'	
d	Box sextant by Troughton 1.64 inch radius, division 30', vernier 1'.	
e	Hand level in brass case.	
f	Gun metal protractor, by Troughton, 5.9 diam, divisions 30'	
g	Mahogany goniometer 11 and 9 inch limbs.	
h	Queen's chamber air channel goniometer,	
j	Sheet steel square, 35 and 45 inches in the sides.	
k	Folding wooden tripod stand, old pattern.	
l	Rigid tripod stand, 30 inches high, octahedral.	
m	Rigid tripod stand, 16 inches high, octahedral.	
n	Rigid iron tripod 12 inches high, octahedral.	
o	12 signals, with plumb bobs.	

The above were all used, most of them continually; a few other instruments were also taken out, but were not needed.

9. Several of these instruments were of new or unusual patterns, which---as well as various fittings adapted to them---require some explanation. The dimensions are all in inches.

(A.) The steel standard and straight-edge was on a new principle, employing the stiffness of a tube to maintain the straightness of a strip. It was skilfully executed by Mr. Munroe, of King's Cross. A steel tube, 102 inches long, 2.0 diam., and .06 thick (see fig. 1, pl. xv.) was supported at the two neutral points, 20.8 per cent. from the ends, resting on two feet at one point and one at the other. This tube carried a series of 15 flat beds, all dressed exactly to a straight line when the tube rested on its supports. These beds supported the actual standard, which was formed of three independent strips of steel, each 34 inches long, 2.0 wide, and .1 thick, butting end to end. These strips bore on the upper face, along the front edge, very fine graduations, the lines being about 1/1000 wide. To ascertain the mean temperature throughout the whole length of the standard, a rod of zinc was screwed tightly to one end of the standard, and bore a scale divided to 1/200 ths at the other end; the scale rising through a slot in the standard. The value of the divisions for various temperatures was carefully ascertained. As this standard was also a straight-edge, the edges of the three strips were all true straight lines, with a mean error of 1/1200 th inch; and the edges were brought into one continuous straight line by adjusting screws set in the supporting beds, at the ends of the Back edge of each strip. The object of having three separate strips was that they could be dismounted for independent use in measuring or drawing. and for testing each other's straightness; that unequal heating of one edge should not cause as much distortion, in length or straightness, as if it were in one continuous piece; and that the weight should not be too great for the rigidity, in handling it when detached from the supports. The principle of separating the stiff part from the actual scale was adopted in order to use the regular drawn weldless steel tube, which is the stiffest thing for its weight that can be had, and also to prevent any unequal heating warping the straightness, as the tube was boxed in by a thin wooden sheath, and so was sheltered far more than the scale could be. The minor details were that strips were held down by screws with countersunk heads, bearing on steel spring washers; and they were pressed Home against each other's ends, and also against the Back adjusting screws, by diagonally acting springs. Along the front of the tube were projecting screws, nutted on and adjusted to form a right angle with the face of the strip; so that the sLandard could be applied to any surface exactly at right angles.

The value of the divisions was ascertained by comparison with a brass standard scale. This scale was tested by Capt. Kater in 1820, 1824, 1830, and 1831; and by the Standards Department in 1875 (see a report on it in the Report of the Warden of the Standards, 1875, Appendix x., pp. 36-41) : as the steel standard was sufficient for comparisons, this scale was not taken to Egypt for fear of injury. The form of this brass standard is a bar, 42.14 long, 1.58 wide, .17 thick; bearing a scale of 41 inches in length, divided to .1 inch, with a vernier of 1/1000 ths, and also bearing a metre divided to millimetres. The steel standard was ascertained, by means of this brass standard, to be exact at 19.6° cent.; and the mean error of graduation and reading combined was .0002, the greatest error being .0005. By the intermediary of a steel tape, the steel standard was further compared with the public Trafalgar Square standard; and according to that it was I in 60,000 longer, or true length at 17.8° cent., or a difference of .021 on the length of the public standard, after allowing for the published error of .019 inch. This is a guarantee that the lcngth of the tape, which was used to transfer from the steel standard to the public standard, has no greater error than this; and, on the whole, I should place as much, or rather more, confidence in the series of comparisons between the Imperial, the brass, the steel standard, and the steel tape, made under the best circumstances in doors, rather than in comparisons between the steel tape, the Trafalgar Square standard, and certain steel rod measures, made in the open air, with wind and varying temperature. The difference in any case is immaterial, in regard to any of the points measured, in the present inquiry.

(B.) The steel tape was over 100 feet long, .37 inch wide, and .008 thick, and weighed just over a pound. It was coiled on an unusually large drum (4.2 diam.), to avoid any chance of permanent distortion. Etched divisions, in the ordinary style, being too ill-defined, I had an unmarked length of tape, and divided it by fine cut lines at every 50 inches ; the position of each line was shown by heating the steel to brown oxidation, and marking the number out of the brown by acid. It was found on trial that such lines did not weaken a piece of tape, even when it was violently twisted and wrenched ; and that the steel, being hard drawn and not tempered, nothing under red heat softened it. The cuts were not put on with any special care, as their exact value was to be ascertained; but the worst error throughout was .0098, the mean error .0039 inch, and the total length true at 19.8° cent. This companson was made when the tape was lying unstretched, on a flat surface, as ascertained by measuring successive 100-inch lengths on the steel standard. It stretched .0127 per lb. on the whole length of 1,200 inches.

(C.) The steel chain of 1,000 inches I made on an entirely new pattern; and it proved, both in Egypt, and, some years before, at Stonehenge, to be very handy in use. Tile links are each 20 inches long, made of wire .092 diam., this being as thin as can be used with fair care. The eyes (see fig. 3, pl. xv.) are wide enough to fold up one in the other, without any intermediate rings. They are rhomboidal, so that they cannot hitch one on the other, but will always slip down when pulled; and the internal curvature of the end of the eye is only just greater than that of the section of the wire, so that the linkage is sure when in use to come to its maximum length.*

***** This is preferable to the type of the standard chain of the Standards Department, as that has such a flat curve at the end of the eye that it is not certan to pull to the maximum length; and in a light thin chain such a form would be liable to bend.

The junction of the eye is made with a long lapping piece, cut one-third away, and tinned to the stern. The whole was tested with 100 lbs. pull, to bring it to its bearings, before marking the divisions. The exact length of the links is unimportant, as, after the chain was made and stretched, a iiarrow collar of sheet copper was soldered about the middle of each link, the collars being adjusted to exactly 20 inches apart. Besides this, each link bore its own number, marked by a broad collar of copper for each 100, and a narrow collar for each 20 inches or link; thus, at 340 inches there were three broad and two narrow collars by the side of the central dividing mark on the link. These collars were put towards one end of the link, apart from the dividing inark, and counted from each end up to the middle, as usual. The central eye of the chain was not tinned up, but was held by a slip clutch; thus the chain could be separated into two 500-inch lengths if needed, each complete in itself, as for base lines for offsets. The handles were kept separately, hooking into any link at which accurate readings under tension might be needed. They were of the same wire as the chain, with wooden cross-bars. One of them included an inverted spring (see fig. 2, pl. xv.), so that the pull compressed the spring. When the pull reached 10 lbs., a small catch (not shown in the Figure) sprang out from the stem, and caught the coils. This left only a very small amount of play; and hence, when using it, the regulation of the tension did not require to be looked at, but was felt by the finger when at 10 lbs. pull. The advantages of this pattern are: (1) Great lightness and compactness of the chain, as it only weighs 2½ lbs., and forms a sheaf 1½ inch diam.; (2) consequent small error by catenary curves, and ease of carrying it clear of the ground by its two ends; (3) accuracy of the divisions; (4) freedom from errors in the linkage; (5) that no counting of the links is required, each being numbered; and (6) that standard tension can be maintained by touch, while the eyes are used on reading the chain length. The worst error of division was .03, the average error .01, and the total length, with 10 lbs. tension, true at 15.8° cent.; the stretching .0l per lb. on the 1,000-inch total length.

(D.) The pine poles were only used for common purposes, being correct to about .02.

(E.F.G.H.) All these rods were divided from the standard scale. I made a right-angled triangle of sheet steel and stout brass tube, to slide along the edge of the standard. It was 13. in its bearing length, with a straight edge 4.3 long at right angles, for ruling by. It carried a fine line on inlaid German silver, by which it was adjusted (with a magnifier) to successive inches of the standard, for the successive cuts to be made. Altogether I divided 80 feet of rods into 1-inch spaces by this, with an average error of .0015 inch. The jointing rods were connected by a slip joint (see fig. 4, pl. xv.); a screw on each rod slipping through a hole in the other, and then sliding in a slot until the rod butted against the stop, S Both the butt and rod ends were made by a screw in the end, sunk up to its head, the screw being screwed in until only slightly in excess, and then ground down to a true length, with a radius equal to the length of the rod. The levelling rods I made with similar jointing and fittings. A base-rod of 60 inches stood on the ground, having a flange against which the upper rods could be slid up or down by hand. It had also a block on the side, carrying a circular level, by which its verticality could be observed. The mode of work was for the staff-holder to hold the base-rod vertical, and slide the upper rods up or down, till a finely divided scale at the top was in the field of the telescope ; then setting the rods, so that one of the inch cuts on them should agree with the zero line on the base-rod, the fractions of an inch were read by the level telescope, and the whole inches reported by the staff-holder. This method enables a larger scale to be used for reading on than if there were similar divisions all down the rods; and yet it takes but little time for adjustment, as that is only done to the nearest whole inch or two, and it does not sacrifice any accuracy. The other scales do not need any remark.

(Q.) The calipers (see fig. 5, pl. xv.) were made for gauging the thickness of the coffer sides; the arms were of equal length, so that variations were read on the scale of their actual value at the other end. The scale was the gun-metal scale, 0, screwed temporarily on to the projection at the top, and read by a line on a brass plate, underlapping it, on the opposite limb. The zero of the scale was repeatedly read, during the series of measurements, by putting an iron bar of known length (±.0002 inch) and parallel ends, between the steel points at the bottom, in place of the side of the coffer. The limbs I made of pine, 71 X 4 X 1, lightened by holes cut through them. The hinge was of steel plates, with copper foil washers between them to prevent friction, and closely fitting on a stout iron pin. The readings of the scale value corresponding to the gauge-piece were four times 5.77, and once 5.76, showing that there was no appreciable shake or flexure in the instrument as used.

(R.) As the steel tape and chain were often used, suspended in catenary curves, two terminal supports were made to hold the ends six inches from the ground. One support was simply a wedge-shaped stand with a hook on it; the other support carried a lever arm, weighted so that it balanced with 10 lbs. horizontal pull from the point where the tape was attached; hence the stand was drawn Back until the arm swung freely, and then there was 10 lbs. tension on the tape. But transferring apparatus was needed, to transfer down from the marks on the tape to the station mark; and to be able to read as instantaneously as if the tape lay on the station mark, for simultaneous readings at each end. After several experiments I adopted a horizontal mirror, levelled in the direction of the tape length, and supported at half the height of the tape. The edge of this mirror being placed just beneath the tape, the reflection of the tape marks could be seen side by side with the station mark; both marks being at the same virtual distance from the eye, and there- fore both in focus together. Motion of the eye does not affect the coincidence, except when the mirror is not level, or not at half the height of the tape; and even then only if large variations occur together. The mirror, its stand, and level, I arranged to pack inside the wedge-shaped terminal support.

(S.) The thermometers were common mercurial and spirit tubes. I graduated them by freezing point, and a hot bath with a fine chemical thermometer in it. Divisions are most easily and visibly marked on the tubes by coating one side with whiting and a trace of gum, then scratching the lines through that with a point; and then fixing, by dipping the tube in thick varnish. The tubes were mounted with the divisions placed behind, and thus much spread out from side to side, as seen through the tube. The wooden frames were thick enough to protect the whole bulb and tube sunk in them ; and the numbering could be safely trusted to the frame, though the accuracy of the divisions was secured on the tube. This plan of seeing the scale through the tube, might be improved on by instrument makers flashing a thin coat of opaque white glass down the Back of the tube, and then etching out the divisions through it.

10. (a.) The principal angular instrument was a splendid theodolite by Gambay, said to have been used by the French in their share of the Anglo- French triangulation. It was of a very unusual form, the support of the upper parts and altitude circle being a pillar formed of the cone axis of the lower or azimuth circle; and the 10-inch or altitude circle being set on a horizontal axis parallel to the plane of it, so that it could be turned over horizontal, as an azimuth circle, with its centre over the axis of the fixed or 7-inch horizontal circle. This was a bold device for making available the full accuracy of the finest of the circles for either altitudes or azimuths, and it was quite successful, as I could never detect the least shake in the converting axis, even though this was taken apart every time the instrument was packed The total weight was so small---being only 37 lbs.---that I could freely carry it, as set up for work, from station to station ; but to avoid straining it in travelling, and to carry it easier over rough ground, it was usually packed in three boxes : one for the 7-inch circle and feet, one for the 10-inch circle, and one for the telescope, levels, and counterpoise. Its original case was ludicrously clumsy, heavy, and dangerous---a sort of thing to need two stout sappers to haul it about, and to take care that it never was turned over.

The 10-inch circle was very finely graduated on silver to 5', the lines being so close as to show diffraction spectra. It was read by four very long verniers of 100 divisions each, one division equal to 3". The magnifying power originally provided was quite inefficient,* being but single lenses of 1½ inch focus.

***** Instrument makers seem to ignore the fact that there is a definite law for the power of reading microscopes; the angular width to the eye of a minute as seen in the telescope should equal the width of a minute as seen in the microscopes, else there must be a waste of accuracy somewhere. The formula is ---focal length of object-glass radius of circle :: focal distance of eye-piece : focal distance of microscope. Of course, in compound eyepieces and microscopes the equivalent focal distance must be employed, inversely to that deceptive term "magnifying power."

One of these I retained for index reading, and then fitted four microscopes of ¼-inch equivalent focus (or magnifying 20 diams. on 5-inch standard, or 40 diams., as opticians are pleased to magnify it) : with these the reading was excellent, the average error of a single reading and graduation. being only .4"; or, combined with errors of parallax, by the planes of the circles being about 1/400 inch different, it was .7". The circle errors were determined by repeating the quadrants of the verniers around it many times, and then going round the circle by stepping the length of each vernier; thus each quadrant was divided up by the mean stepping of four vernier lengths of 8¼º each. These four values were mapped in curves, and a mean cune was drawn through them ; this mean curve was ever after used (along with corrections for level, &c.) in correcting all the observations of each vernier independently, so as to - detect any extraordinary error or reading. The instrumental errors were all small : the eccentricity of the circles was in the I0-inch = 4.8", in the 7-inch = 15.5"; the difference of axes of inner and outer cones of repeating motion = 5.2"; the difference between the two ends of the transit level-bearing and the steel pivots sunk in them = 6.6"; the difference of the diameters of the pivots, and their errors of circularity, inappreciable. The runs of the four verniers were .42", .92", .25, and .12" on 5' or 300". Of course, in field work, the errors of pointing, of vibration of the instrument, and personal errors due to wind, sand, heat, glare, and constrained positions, increased the mean error of reading ; and, on the average, it is 1.1" for a single observation.

The 7-inch circle was scarcely ever used ; the long cone of it was so finely ground that, on being set on an ordinary table (soon after I had thoroughly cleaned it), the whole of the upper part of the instrument (about 18 lbs. weight) was seen to be slowly revolving in azimuth, without any apparent cause. On examining it, it was found that, not being quite level, and the counterpoise of 5 lbs. not being put on it, its centre of gravity was not at the lowest point attainable ; hence the rotation. The telescope was equal in character to the rest of the instrument, the object-glass being 1.66 diam., and 16¼ inches focal length, and the eye-piece of high power and large field; thus it magnified 35 diameters. The form of the slow motions was far superior to that of English instruments ; all the tangent screws had a steel ball on the shank, which worked between two circular holes, in plates which were clamped together by a fixed screw; the nuts were also spherical, cut into two separate halves, and also clamped between circular holes. Thus there was practically perfect absence of shake, and great working smoothness, even when stiffly clamped. Another excellent device was the use of spring steel washers to all screws whose tension was in question; the screws were all made to run dead Home on a seat, and to produce pressure through a curved washer, which they flattened, either for fixed tension, or for rotation of an axis. Thus a slight loosening of a screw made no difference or shake and no delicate tightening up was needed; if the pressure had to be altered, the washer was taken out and bent accordingly.

The three levels of the theodolite were suitably delicate, the value of one division being 2.47" (altitude), 4.92" (transit), and I2.8" (cross level). For these and every other level used, I adopted a distinctive system of numbering. Every level had a different number for the mean position of the bubble end, and the divisions were numbered uniformly in one direction, and not simply on each side of the mean. Thus the ranges were respectively from 5 to 15, 16 to 24, 28 to 32, 40 to 60, &c., on the levels called No.10, No.20, No.30, No.50, &c.; and when once a number was recorded (the mean of the two ends was always taken mentally), it showed which level was read, and in which direction, with any doubt, or further note.

Other adjuncts that I provided for this, and also for the other theodolites, were slit caps (see figs. 6, 7, 8, pl. xv.). It is manifest that objects seen through a fine hole are always in equally good focus, no matter what maybe the distance; hence, if an object-glass is limited to a small hole, it does not need focussing. But definition is commonly required in only one direction at once, either vertically or horizontally; hence a slit ---which admits more light--- will be as effective as a hole. When a line is quite invisible, by being out of focus, placing a slit cap over the object-glass, parallel with the line, will make it clear ; and it will be well defined in proportion to the fineness of the slit. Each of the theodolites were therefore fitted with two movable slit caps, fine and wide, to cover the object-glasses. As focussing is always liable to introduce small errors, by shake of the tubes in each other, these slit caps were adopted to avoid the need of changing focus continually from near to distant objects; they also serve to bring near points in view, at only a foot or two from the glass. To be able to place the slit-cap on the end of the telescope, without shaking it, was essential. This I did by making the slit of thin steel spring; soldered to brass clutches, so as to grip the telescope by three points; provided also with a projecting tongue above, and another below it, whereby to bend it open for clipping it on (see figs. 6, 7, 8, pl. xv.). The smaller theodolites were also fitted with diagonal mirrors clipping on to the object-glass ; these enabled the instruments to be very accurately centred without a plumb-line.

(b.) The 5-inch theodolite, by King, was an old one, and was obtained for rough work; but it had never been adjusted, so I had to take it in hand; and on finding its errors, after correction, to be even less than those of the 4-inch Troughton, I generally used it for all small work. I corrected it in the rectangularity of cones to the circles, of transit axis to the cones, and of cradle axis to transit axis; also in adjustment of verniers for run. The telescope was of long focussing-range when I got it, and I increased the range from infinite down to 5½ feet focus, which made it very useful in near levelling, as in buildings; also I did away with the mere fit of sliding tubes for focussing; and made the inner tube run on four points, slightly punched up in the outer tube, and pressed in contact with them by a spring on the opposite side of it. The old level I replaced by a good one of Baker's, running 41.5" to .1 inch. Microscopes of ¼ inch equivalent focus were fitted to two arms, which were slipped together when required for use, and rode round on the compass-box; with these the average error of reading on the 1' verniers was 7".

The spider lines in this, and the next theodolite, were somewhat different to the usual pattern. When either a single vertical line, or a diagonal cross, is used, it blocks out any very small signal; and I have even heard of an engineer hunting in vain for his signal, because the line exactly hid it. To ensure greater accuracy, I therefore put in two parallel lines, crossed by one horizontal (needed for levelling) ; the lines being about 1/400 inch apart; if closer they may cling together if vibrated, and it is awkward to separate them while in the field. Thus the interval of the vertical lines was about 1', and signals could be very accurately centred between them.*

***** Spider line from webs is useless, as it is covered with sticky globules to catch small flies; the path-threads of the spider are clean, but thick; so that the best way of all is to catch a very small spider, and make it spin to reach the ground, winding up the thread as fast as it spins it out, dangling in mid-air.

(c.) The 4-inch theodolite by Troughton was not often used, except where lightness was important; I fitted it with two microscopes, similarly to the 5-inch; and its mean error of reading was about 8" on the I' vernier.

Though neither of these were transit theodolites, yet in practice I used them as such for all accurate work. By reversing the telescope, end for end, and upside down, and turning the circle I80º, all the errors are compensated as in a transiting instrument; the only extra source of error is irregularity in the form of the rings, which can be tested by revolving the telescope in its cradle.

(h.) For ascertaining the angles of the Queen's Chamber air channels I needed to measure as long a length of slope as possible, at about 8 feet inside a passage which was only .8 inches square. For this I pivoted an arm on the end of a long rod (see fig. 9, pl. xv.), and passed it into the passage in the dotted position at A; on reaching the slope it turned itself up to the angle by pressure, the main rod touching the passage roof. The arm carried an index, which touched a scale attached to the main rod. This scale was divided by actual trial, by applying a protractor to the limbs and marking the scale. To read it, a candle was carried on an arm, which shaded the direct light from the eye; and the scale was inspected by a short-focus telescope. Thus the readings were made without needing to withdraw the goniometer from the narrow channel, and hence the arm of it could be much longer than would be otherwise possible.

(j.) A large square, 35 and 45 inches in the sides, of sheet steel strips, 2 inches wide, and tinned together, I made for testing angles; it was not exactly adjusted to squareness, but its angles were very carefully fixed, by triangulating a system of fine punched dots on the face of it; and the edges were adjusted straight within about .003 throughout their length. It could be used for the absolute value of slopes of about 51º 50' and 26º 20', by means of a rider level placed pn one edge of it, and reading by means of a divided head screw at one end. To render the square stiff enough sideways, it was screwed down (with round projecting screw heads, not countersunk) to a frame of wooden bars, 2 x 1 inch in section. I generally found, however, that it was best to measure a slope by theodolite and offsets.

(k, l, m, n,) These stands were used for the theodolites. Generally the 10-inch theodolite could be placed directly on the rock, or on a stone; but when a stand was needed I used one about 30 inches high, that I made of 1 X 1 pine rod; the top was stouter and about 12 inches triangle, and the feet about 30 inches apart, connected by cross bars. Thus it was of the octahedral pattern, a triangular face at the top, another at the base, and six faces around; this being the only form absolutely free from racking. The screw feet of the theodolite rested on leaden trays on the top of the stand, which allowed free sliding for adjusting its centring. A similar octahedral stand about 16 high, was made of ½ X 1 inch pine, for the 5-inch theodolite; in order to stand it in chambers or on stones. The instrument was clamped on to the stand by a screw from beneath, passing through a plate under the triangular top of the stand, and screwing into the base plate of the theodolite, which rested upon the top of the stand. Thus it could be slid about on the stand, to adjust its centring, and then clamped tight after wards. The iron stand was of just the same pattern, but made of ¼ inch iron rod; the rods were bent parallel where joined, and passed into sections of iron tube, the whole filled up with tinning. These small stands would stand on the top of the large one when required.

(o.) For signals in the triangulation, to show the places of the station marks, I made a number of short wooden cylinders, 1¼ diam., painted white, and standing on three legs of wire (see fig. 10, pl. xv.) In order to enable these to be centred over the station marks by a plumb-bob, the cylinder was cut in two across the middle; a diaphragm of thin card was then put in it, with a hole truly centred by adjusting a circle on the card to the outline of the cylinder; and the two halves of the cylinder were pegged together again. Then, having a plumb- bob hanging by a silk thread through the hole, at whatever angle the cylinder could stand the bob would be always beneath its centre. The bob was fixed to hang at the right height, according to the irregularities of the rock, by drawing the thread through the hole, and pressing it down on a dab of wax on the top of the cylinder.

The plumb-bobs are all of a new pattern (see fig. 11, pl. xv.) The point of suspension is generally too near to the centre of gravity, so that a slight shift in it would move the position of the lower end a good deal more. Hence the suspension and the end of the bob are here made equidistant from the middle. To avoid the complication of screw plugs to each bob, there was a large horizontal hole through the neck, to hold the knot; and a smaller vertical hole in the axis of the bob for the thread to pass.

The finest white silk fishing line was found to be the best thread for plumb- lines, or for stretching for offset measures ; it does not tend to untwist, or to spin the bob; it is only 1/50 inch diam., well defined and clean, and very visible. Wax is invaluable for hanging plumb-lines in any position; and a piece of wood an inch square, well waxed, if pressed against a stone warmed by a candle, will hold up several pounds weight.

For station marks on rocks or stones, I entirely discarded the bronze and lead forms. They may be very good in a law-abiding country, but I found that half of those put down by Mr. Gill, in 1874, were stolen or damaged in 1880. The neat triangular stones in which they were sunk also attracted attention. I therefore uniformly used holes drilled in the rock, and filled up with blue-tinted plaster; they are easily seen when looked for, but are not attractive. To further protect them, I made the real station mark a small hole .15 diam. ; and, to find it easier, and yet draw attention from it if seen, I put two ½ inch holes, one on each side of it; usually 5 inches from it, N.E. and S.W. Thus, if an Arab picked out the plaster (which would not be easy, as the holes are 1 to 1½ inches deep) he would be sure to attack a large hole, which is unimportant. Where special definition was wanted, as in the main points round the Great Pyramid, a pencil lead was set in the middle of the plaster. This cannot be pulled out, like a bit of wire, but crumbles away if broken; and yet it is imperishable by weathering. To clean the surface of the marks, if they become indistinct, a thin shaving can be taken off the rock, plaster, and central graphite altogether. Where I had to place a stone for a station mark, I sunk it in the ground; and for the base terminals I took large pieces of basalt, and sunk them beneath the surface; thus a couple of inches of sand usually covers them, and they cannot be found without directions.

On reading this description of the instruments, it might be asked what need there could be for doing so much in adjustment, alteration, and manufacture, with my own hands. But no one who has experienced the delays, mistakes, expense, and general trouble of getting any new work done for them, will wonder at such a course. Beside this, it often happens that a fitting has to be practically experimented on, and trials made of it, before its form can be settled. And, further, for the instinctive knowledge of instruments that grows from handling, cleaning, and altering them, and for the sense of their capabilities and defects, the more an observer has to do with his own instruments the better for him and for them.

11. For the general questions of the principles of the arrangement of a triangulation, and of the reduction of the observations, we must refer to the two appendices on these subjects. They are so purely technical, and uninteresting to any but a specialist, that they are therefore omitted from the general course of this account. We begin here with lineal measure, and then proceed to angular measure, including tbeodolite work in general.

For lineal dimensions, I always used the system of a pair of rods butting end to end, and laid down alternately, instead of making marks at each rod length. In testing measures, the value of the sum of two rods can also be obtained more accurately than the exact butt length of either of them alone. But for the more important points, the direct measurement of a space by a rod has been often abandoned for the more accurate method of referring all parts to horizontal and vertical planes of known position. This is a necessary refinement when precision is needed, and it specifies a form in every element of size, angle, and place. In the passages, where the use of horizontal planes was impracticable, a plane at a given angle was adopted, and the roof and floor were referred to that.

In the Great Pyramid, the King's Chamber was measured by hanging a plumb-line from the roof in each corner of the room; and measuring the offsets from the lines to the top and bottom of each course on each side of the corner. Then the distances of the plumb-lines apart were measured by the steel tape on the floor. The heights of the courses were read on a rod placed in each corner. For the levels, the 5-inch theodolite was placed just about the level of the first course; then at 24 points round the side a rod was rested on the floor, and the level and the first course read on the rod.

The coffer was measured by means of a frame of wood, slightly larger than the top, resting upon it; with threads stretched just beyond the edges of the wood, around the four sides. The threads gave true straight lines, whose distances and diagonals were measured. Then offsets were taken to the coffer sides from a plumb-line hung at intervals over the edge of the wood; its distance from the straight stretched thread, being added to the offsets, thus gave the distances of the coffer sides from true vertical planes of known relation to each other, at various points all over the sides. Similarly, the inside was measured by a frame, slightly smaller inside it than the coffer. The bottom was measured by raising the coffer 8 or 9 inches; the theodolite was placed to sight under it, and offsets were thus read off to the outside bottom from a level plane, also reading the height of the plane of sight on a vertical rod; then the theodolite was raised so as to sight over the top of the coffer, the height of its plane on the same fixed rod was read off to give its change of level, and then long offsets were taken to points on the inside bottom of the coffer. Thus the thickness of the bottom is determined by the differences of level of the theodolite, minus the two offsets. Besides this, a check on the sides was taken by a direct measurement of their thickness with the pair of calipers already described.

The antechamber was measured in the common way; but the granite leaf in it had a bar placed across the top of it, with a plumb-line at each end of the bar, ie., N. and S. of the leaf. The distances of the lines apart were taken below the leaf, and offsets were taken all up the leaf on each side; this was done at each end and in the middle of the leaf.

In the Queen's Chamber two plumb-lines were hung from the ends of the roof-ridge, their distance apart observed, and offsets taken to the side walls and to the ends. Offsets were also taken to the niche, which was, beside this, gauged with rods between its surfaces all over. The heights of the courses were also measured in each corner. The angles of the air channels were read by the goniometer already described.

The subterranean chamber was measured in the common way, with rods along the sides, but the irregularity of the floor, and the encumbrance of stones left by Perring made it very difficult to measure.

12. Turning next to measurements made with the theodolite, these generally included some determination of angular as well as lineal quantities. The straightness of the sloping passages was uniformly observed by clamping a theodolite in azimuth, pointing along the passage, and having a scale held as an offset against the wall at marked intervals; thus variations in azimuth of the passage were read. On reaching the end, the assistant holding the scale stopped, the theodolite was clamped in altitude instead of in azimuth, and the assistant returned, holding the offset

scale to the floor or roof; thus variations in slope of the passage were read. The whole length of the entrance passage, and the ascending passage and gallery in one length, were thus measured. For the air channels on the outer face, where the floor is unbroken, a slip of board carrying a perpendicular mirror was let down the channel by a string, in lengths of 10 feet at a time ; and the dip to the reflection in the mirror was noted by a theodolite at the mouth. It is then a matter of mere reduction to obtain the variations from a straight mean axis.

The horizontal measurements outside the Pyramid were entirely performed by triangulation ; and this included in a single system the bases of the three larger Pyramids, the pavement of the Great Pyramid, the trenches and basalt pavement on the E. side of the Great Pyramid, and the walls around the Second and Third Pyramids. The Great Pyramid was comprised in a single triangle. This triangulation by means of the 10 inch theodolite occupied some months in all; some angles being read 14 times, and the fixed stations being about 50 in number, besides about as many points fixed without permanent marks. The first-class points were fixed with an average probable error of .06 inch; and the least accurate points, such as those on the rough stone walls, were fixed within I or 2 inches. For fixing the points uncovered by excavation, a rod was placed across the top of the hole, and a plumb-line dropped from it to the point to be fixed. A theodolite was then placed near it, and was fixed in the triangulation by reference to known stations; tbe distance of the plumb-line from the theodolite, was then measured by the angle subtended by divisions on the horizontal rod which supported it.

For connecting together the inside and outside measurements of the Great Pyramid, a station of the external triangulation was fixed on the end of the entrance passage floor, thus fixing the position of the passage on the side of the Pyramid. From this station the azimuth down the passage was observed thus fixing the direction of the passage. And levelling was also carried up from the pavement and casing stones of the N. face to this station; thus fixing the level of the passage, and hence that of all the interior of the Pyramid. The positions of the passages of the Second and Third Pyramids, on their faces, were also fixed in the triangulation.

The base of the survey was thrice measured, with a probable error of ± .03 inch (or 1/260,000 of the whole) by the steel tape. To avoid the need of. a truly levelled base line, a series of blocks of stone was put between the terminals of the base, which are 659 feet apart; a stone was placed at each tape length (1,200 inches), and at each chain length (1,000 inches); and a sufficient number of stones were placed also between these, as to support the chain or tape in catenary curves throughout, with the usual 10 lbs. tension. The stones thus varied from 140 to 393 inches apart. Then, the distances and levels of the stones being known, the reduction to be applied to the tape as it lay on them to ascertain its horizontal length, were easily applied. No attempt was made to place a mark at exactly each tape length on the stones; but a scale of 1/50ths of an inch was fixed temporarily on each stone at which the tape lengths joined; then the two ends of the tape were read simultaneously on the scales several times over, slightly shifting the tape each time in order to equalize the friction of its support: thus the distances of the zeros of the scales placed all along the base were ascertained, and hence the total length of the base.

For the height of the Great Pyramid a line of levelling was run up the SW. corner, across the top, and down the N.E. corner, stepping 15 to 20 feet at each shift. Separate lines of level were twice run round the Pyramid, (including the basalt pavement, &c.), and the differences were under ¼ inch, both between them and from the levels of Mr. Inglis, excepting his S.E. socket. Thus a complete chain, from N.E. to S.E., to S.W., to top, across top, and to N.E. was made; and the difference was only ¼ inch on the return, the total run being 3000 feet distance, and 900 feet height. Besides this, an independent measurement by rods had been carried up each of the four corners of the Pyramid to the top; generally two, and sometimes three or four, steps were taken in one length, and levelled to the nearest, 1/10 inch, from the upright rod to the upper step, by a reversible horizontal rod with level attached. The intermediate courses in each length were also measured off This gives all the course heights, and is regulated at every 10 or 20 courses by the accurate levelling on the N.E. and S.W. The same point was always used on each step, both in the measuring and the levelling, so as to avoid errors of levelling and dressing in the steps; and each tenth course has a cross scored on the stone, at the point used in the levelling. The Third Pyramid was only measured by rods up the courses.

The angles of the ascending passages were not retaken, as Professor Smyth had already done that work fully; but the angle to the bottom of the entrance was observed by the 10-inch theodolite, placed on a shelf across the mouth of the passage. The levels of the horizontal passages were taken with the 5-inch theodolite, placed in the middle, and reading on both ends. The level from the entratice passage to the ascending passage was read off on a single vertical rod placed in Mamun's Hole; a theodolite being put first in the lower and then in the upper passage to read on it.

As a general principle, in observing down a passage with a theodolite, no dependence was placed on measuring the position of the theodolite, which was usually outside the passage in question ; but in all cases a signal was fixed in the passage near the theodolite, as well as one at the farthest point to be observed, and the azimuths of both were noted; the distances being roughly known, the minute corrections to be applied to the azimuth of the further signal could be readily determined. The azimuth observations of Polaris always included a greatest elongation. For the dip of the entrance passage the l0-inch theodolite was clamped in altitude, at closely the true angle; an offset was taken to the roof at the bottom, and the theodolite was reversed and re-read as usual to get the dip, reading level at the same time. Offsets were then read to points all up the roof keeping the telescope clamped in its second position; thus it was not necessary to know the exact height of the plane of the roof above the theodolite. The azimuth of the entrance passage was determined down to Mamun's Hole, by connection with the triangulation, whose azimuth is otherwise known; and it was also determined down to the bottom by Polaris observations. The azimuths of the horizontal subterranean passages were read by the signal at the top, and on candles placed in the passages ;* the S. end of the S. passage being invisible from the theodolite, its candle was sighted on in line with its N. end candle, and the line measured off in the chamber.

* Naked candles are good objects for observing on, where there is no wind; the spot of flame, the candle, or the thin wick, serving at different distances; offset measurements can also be taken accurately to the wick. Lanterns were only used for outside work.

The azimuth of the ascending passages was measured by three theodolites used together; all of the telescopes were set to infinite focus, so as to see each other's cross wires plainly when a candle was held behind the telescope observed on. The 10-inch was put in the entrance passage, reading on a signal at top, and on the 5-inch; the latter was placed on the rubbish in Mamun's Hole, reading on the 10-inch and 4-inch; and this last was placed just above the granite plug blocks, reading on the 5-inch and on a signal at the top of the ascending passage. Thus a chain of angles was formed from signal to signal, quite free from any errors of centring the theodolites or station marks. For the angle of the Great Pyramid casing stones in situ , the 10-inch theodolite was placed on the steps above; the dip was read to points on the top of the casing stones, and on the pavement in front of them; and then offsets were measured from these points to the face of the stone. The Second and Third Pyramid casing was measured by goniometer and protractor.

Thus it will be seen that several fresh methods of observation have been introduced, in order to obtain greater accuracy and more information : in particular the methods of plumb-lines and optical theodolite-planes, with offsets from these, have yielded good results. A fresh feature in the discussion of observations is the introduction of "concentrated errors;" on the principle of showing all the divergences from regularity on their natural scale, while reducing the distances of the parts so that they may readily be compared together. This is the essential basis of the method of graphic reduction, described in the Appendix (shown in Traces of Observations, P1. xvi; and it renders possible the use of graphic methods in work of any delicacy; it is also exemplified in the diagrams of the King's Chamber walls P1. xiii, and of the relation of the casing and pavement P1. x

13. In Egypt all excavations are forbidden, and a special permission is required for any such researches, the law of treasure-trove being the same as in England. Having in I880-1 done all the triangulation of my station marks, it was requisite in 1881-2 to connect them with the ancient points of construction. For this, therefore, I needed permission to excavate, and applied to M. Maspero, the courteous and friendly director of the Department for the Conservation of Antiquities; Dr. Birch kindly favouring my request. In order to save delay and needless formalities, M. Maspero at once said that he would permit me to work under his firman, on all the points that I had indicated to him in writing; the Bulak Museum being formally represented by a reis, who would observe if anything of portable value should accidentally be discovered, though such was very unlikely and unsought for. Under this arrangement, then, I carried on excavations for about six weeks, having during most of the time about 20 men and boys engaged. The total expense was only about £18, or £22 including the reis of the Museum. He was a son of old Reis Atweh, who worked for Prof Smyth ; a very polite man, who quite understood that his presence was a formality.*

* A notice of these excavations appeared at the time in the *Academy* of 17th December,

The first work that needed to be done (and that quickly, before the travellers' season set in) was to open the entrance passage of the Great Pyramid again to the lower chamber. The rubbish that had accumulated from out of Mamun's Hole was carried out of the Pyramid by a chain of five or six men in the passage. In all the work I left the men to use their familiar tools, baskets and hoes, as much as they liked, merely providing a couple of shovels, of picks, and of crow-bars for any who liked to use them. I much doubt whether more work could be done for the same expense and time, by trying to force them into using Western tools without a good training. Crowbars were general favourites, the chisel ends wedging up and loosening the compact rubbish very easily; but a shovel and pickaxe need a much wider hole to work them in than a basket and hoe require; hence the picks were fitted with short handles, and the shovels were only used for loose sand. In the passage we soon came down on the big granite stone which stopped Prof. Smyth when he was trying to clear the passage, and also sundry blocks of limestone appeared. The limestone was easily smashed then and there, and carried out piecemeal ; and as it had no worked surfaces it was of no consequence. But the granite was not only tough, but interesting, and I would not let the skilful hammer-man cleave it up slice by slice as he longed to do; it was therefore blocked up in its place, with a stout board across the passage, to prevent it being started into a downward rush. It was a slab 20.6 thick, worked on both faces, and one end, but rough broken around the other three sides ; and as it lay flat on the floor, it left us 27 inches of height to pass down the passage over it. Where it came from is a complete puzzle ; no granite is known in the Pyramid, except the King's Chamber, the Antechamber, and the plug blocks in the ascending passage. Of these sites the Antechamber seems to be the only place whence it could have come; and Maillet mentions having seen a large block (6 feet by 4) lying in the Antechamber, which is not to be found there now. This slab is 32 inches wide to the broken sides, 45 long to a broken end, and 20.6 thick; and, strangely, on one side edge is part of a drill hole, which ran through the 20.6 thickness, and the side of which is 27.3 from the worked end. This might be said to be a modern hole, made for smashing it up, wherever it was in situ ; but it is such a hole as none but an ancient Egyptian would have made, drilled out with a jewelled tubular drill in the regular style of the 4th dynasty; and to attribute it to any mere smashers and looters of any period is inadmissible. What if it came out. of the grooves in the Antechamber, and was placed like the granite leaf across that chamber? The grooves are an inch wider, it is true; but then the groove of the leaf is an inch wider than the leaf. If it was then in this least unlikely place, what could be the use of a 4-inch hole right through the slab? It shows that something has been destroyed, of which we have, at present, no idea.

Soon after passing this granite, we got into the lower part of the entrance passage, which was clear nearly to the bottom. Here a quantity of mud had been washed in by the rains, from the decayed limestone of the outside of the Pyramid, thus filling the last 30 feet of the slope. This was dug out and spread narrow passage; no truck arrangement could be easily worked, owing to the granite block lying in the passage. Work down at the bottom, with two lanterns and six men, in the narrow airless passage, was not pleasant; and my visits were only twice a day, until they cut through to the chamber. Here I had the rest of the earth piled up, clear of the walls, and also of the well, and so re-established access to these lower parts.

In the well leading from the gallery to the subterranean passages, there is a part (often called the "Grotto") cased round with smalI hewn stones. These were built in to keep Back the loose gravel that fills a fissure in the rock, through which the passage passes. These stones had been broken through, and much of the gravel removed; on one side, however, there was a part of the rock which, it was suggested, might belong to a passage. I therefore had some of the gravel taken from under it, and heaped up elsewhere, and it was then plainly seen to be only a natural part of the water-worn fissure This well is not at all difficult to visit; but the dust should be stirred as little as possible. One may even go up and down with both hands full, by using elbows and toes against the sides and the slight foot-holes.

14. The next business was to find the casing and pavement of the Great Pyramid, in other parts beside that on the N. face discovered by Vyse: the latter part had been uncovered, just when I required it, in 1881, by a contractor, who took the chips of casing from the heaps on the N. face to mend the road. Thus the tourists to the Pyramid actually drive over the smashed-up casing on their way. On the three other sides the Arabs had some years ago cut away a large part of the heaps of casing chips, in search of pieces which would do for village building. Thus the heaps were reduced from about 35 to only 20 feet in depth, over the middle of the base sides of the Pyramid ; though they were not touched at their highest parts, about 40 or 50 feet up the sloping side of the Pyramid.

The shafts for finding the casing were then sunk first of all about 100 feet from the corners of the Pyramid; and then, finding nothing there but rock (and that below the pavement level), places further along the sides were tried; until at last the highest parts, in the very middle of the sides, were opened. There the casing and pavement were found on every side, never seen since the rest of the casing was destroyed a thousand years ago. Thus for the North casing four shafts were tried ; but no casing was found, except where known by Vyse. On the East side four shafts were sunk, finding casing in the middle one. On the South four shafts were sunk, finding badly preserved casing in one, and good casing in another, entirely eaten away, however, just at the base (see P1. xii.). On the West side five shafts were tried, finding casing in one of them, and pavement within the casing line at the N.W. The East and South casing was seriously weathered away; on the East it was only defined by the pavement being worn away outside its ancient edge; and on the South it was found to be even hollowed out (P1. xii.), probably by the action of sand whirled up against the base, and scooping it out like sea-worn caves. The shafts were cut as small as possible, to avoid crumbling of the sides ; and they were steined with the larger blocks where the rubbish was loose : ledges were left at each six feet down, for the men to stand on for handing up the baskets and larger stones. The Arabs never would clear away the loose stuff from around the shafts, without having special directions; and often there was a long slope of 15 feet high of rubbish, just at the angle of rest, over one side of a shaft: this needed to be cut away and walled Back. Both the excavators and myself had narrow escapes from tons of stuff suddenly slipping in, sometimes just after I or they had been at the bottom of the shaft: the deep Southern shaft no one but Negroes would work in at the last. As I did not uncover the casing on the North side, I did not oonsider it incumbent on me to cover it over again; and the casing down the shafts is safe from damage, as it is too troublesome and dangerous for the Arabs to try to break it or carry it off: it would be far easier for them to work out more loose pieces from the rubbish.

Besides these shafts, many pits and trenches were dug to uncover the outer edge of the pavement. For the basalt pavement, the edge of the rock bed of it was traced on N.E. and S.; but no edge could be found on the West. It was cleared at the centre, where the trenches converge, and was there found to be all torn up and lying in confusion, along with many wrought blocks of red granite. Further out from the Pyramid it was perfect in some parts, as when first laid. The trenches were cleared at the ends, where necessary; the North trench was dug into as far as nine feet below the sand at present filling it, or about eighteen feet below the rock around it, but nothing but sand was found ; the E.N.E. trench was cleared by cuttings across and along it, so as to find the bottom of each part, and make certain that no passage led out of it; the N.N.E. trench was cleared by pits along it, and traced right up to the basalt pavement The trench near the N.E. corner of the Pyramid was cleared in most parts, and the rock cuttings around it were also cleared, but re-filled, as the carriage road runs over them. Thus altogether 85 shafts, pits, or trenches were excavated around the Great Pyramid.

15. At the Second Pyramid it was not so necessary to find actual casing, as it was arranged differently: the bottom course of casing had an upright foot 10 or 12 inches high, at the bottom of its slope, not ending in a sharp edge, like the Great Pyramid casing, which was very liable to injury. The end of the slope being thus raised up already some way, the pavement was built against the upright face, and to get depth enough for the paving blocks, the rock outside the casing was cut away. Thus the casing actually stood on a raised square of rock, some few inches above the rock outside it (see P1. xii.), and the edge of this raised square was further signalized by having holes along it (5 to 10 inches long and about half as wide), to receive the ends of the levers by which the blocks were moved. This arrangement is very clearly shown near the W. end of the S. side, where a block of casing remains, but slightly shifted ; and therefore, where this raised edge was found in other parts, it was accepted as being equivalent in position to the foot of the casing slope, without needing to find actual casing in each place.

At the N.E. corner the raised edge was found, scarcely covered over. On the E. side two pits were sunk, and the edge was found in one at the S. end. The edge was cleared at the S.E. corner. On the S. side the edge was found at the E. end, and the casing in situ cleared at the W. end. The S.W. corner of the edge was cleared. On the W. side the edge was found at the N. end. The N.W. corner was cleared, but no edge was found there. On the N. side the edge was found at the W. end. Thus the raised edge was found and fixed at eleven points around the Pyramid. The joints of the platform of huge blocks on the E. of it were partly cleaned to show the sizes of the stones. Three pits were tried on the N.W. of the Pyramid, and the edge of the rock bed of the pavement was found in two of them. Two trenches were made to examine the edge of the great rock cutting on the N. side of the Pyramid.

Twenty-three trenches and sixty-seven pits were dug to uncover parts of the great peribolus walls of this Pyramid. Thus it was found that all the heaps and ridges, hitherto called "lines of stone rubbish," were built walls of unhewn stone, mud plastered, with ends of squared stone, like antæ. The great barracks, consisting of a mile and a half length of galleries, was thus opened. Many fragments of early statues in diorite, alabaster, and quartzite, were found, as well as early pottery, in the galleries ; though not a five-hundredth of their whole extent was uncovered. The great hewnstone wall, built of enormous blocks, on the N. side of the Pyramid, was examined by pits; and quarry marks were found on the S. sides of the blocks. Two retaining walls of unhewn stone, like those of the galleries, were found in the large heap of chips, which is banked against the great N. wall. These retaining walls contained waste pieces of granite and basalt. The great platform of chips, tipped out by the builders beyond the S. peribolus wall, was cut into in two places. Some early pottery was found ; and it was evident, from the regular stratification, that it had been undisturbed since it was shot there in the time of Khafra. Altogether, 108 pits and trenches were opened around the Second Pyramid.

16. At the Third Pyramid it was necessary to clear the casing at the base level; and this was a more troublesome place to work on than any other. Howard Vyse reports that he abandoned his work here on account of the great difficulty and danger of it. The material to be removed consists entirely of large blocks of granite weighing a ton and upwards, which lie embedded in loose sand; hence, whenever the sand was removed in digging a hole, it ran down from the sides, and so let one of the large blocks drop into the hole. The most successful way of getting through it was to bring up other stones and place them so as to form a ring of blocks wedged together around the hole, and thus supporting one another. As there is no clear setting for the casing here as there is in the Second Pyramid, and as the substratum had been removed at the eastern corners, it was necessary to find the casing foot near each end of the sides, and not to trust to the corners. There was no difficulty in finding casing stones, as the casing still remains above the rubbish heaps on every side; the work was to get down to the foot of it. This was done at the E. end of the N. side, at both ends of the E. side, at both ends of the S. side, and at the S. end of the W. side. The N.W. corner was very deeply buried, and several trials were made to get down, but without finding any place sufficiently clear of the great granite blocks; here, therefore, I had to be content with fixing the edge of the fifth course of casing, which stood above ground, and projecting this down at the observed angle by calculation. Seven points in all were thus fixed, of the intended finished surface of the original casing at the bottom course. Besides this, eighty-four pits were made along the peribolus walls of this Pyramid; these holes showed that the walls were all built like those of the Second Pyramid, but less carefully. Ninety-one pits in all were made around the Third Pyramid. This makes a total of 284 shafts, pits, or trenches, sunk in the hill of Gizeh ; and in almost every case the objects sought were found.

17. Some few details may be useful to future explorers. The tools used were the ordinary native forms, with a few English tools for special purposes, as have been described. Of supervision the Arabs require a good deal to prevent their lounging, and Ali Gabri looked well after them, proving zealous and careful in the work: I, also, went out with them every morning, allotting their work for the day; then visiting them generally just before noon; and again before they left ofi, in the afternoon. Going thus round to six or eight places some way apart, and often stopping to direct and help the men, occupied most of the day. It is particularly necessary never to put more men on a spot than are absolutely needed to work together; generally each isolated party was only a man and one or two boys ; thus there was no shirking of the individual responsibility of each man to get through his work. Every man was told what his party had to do, and if they were lazy, they were separated and allotted with good workers, where they would be closely watched. The men were allowed to choose their work somewhat, according to their strength and capabilities; and if any man grumbled he was changed to different work, or dismissed. A very friendly spirit, with a good deal of zeal to get through tough jobs, was kept up all the time by personal attention to each man, and without any extra stimulus of bakhshish, either during or after the work. The wages I offered, and freely obtained labour for, were rather above what excavators are required to work for by the Museum ; but were far less than what had been paid there before by Europeans. For ordinary work the rate was 10d. a day, and 6d. for boys; for work inside the Pyramid, 1 shilling a day, and 7½d. for boys. The men were paid weekly, and no attempts were made to impose, as I kept a daily register of the number employed. Ali received what I always paid him while I was living there, £1 a week, and 4 shillings for his slave and nephew sleeping in the next tomb as guards ; for this he was always at my disposal for work (though I did not occupy half of his time), and he made all purchases and arrangements with the neighbours, besides keeping me quite free from molestation or black-mailing by the other Arabs.

18. The station marks of the triangulation consist of holes drilled in the rock or stone, and filled with blue-tinted plaster, as already described; sec. 10. Where great accuracy was needed a graphite pencil lead was put vertically into the plaster. Thus the mark may be scraped clean, if bruised or defaced, without destroying the mark. To enable the station-mark holes of about 1/6-inch diameter to be readily found, and at the same time to draw off attention from them, two ½ -inch holes, similarly filled, are drilled, in most cases one on each side of each station mark, at 5 inches from it, to the N.E. and S.W. I also utilized some few of Mr. Gill's bronze station marks, that had escaped the attention of the Arabs. The less important stations, of the rock trenches, are merely marked by a single ½ -inch hole, filled with blue plaster. The general position of the station marks are shown in the plan of the triangulation on Pl. 1.

19. The co-ordinates of the station marks, &c., are reckoned from a line beyond the N. side of the whole area, and from a line beyond the E. side of the area: thus there are no minus quantities. The azimuth of true North on the system of co-ordinates is East of the approximate North of the system, or the azimuth of its Eastern boundary, by

$$+ 1^{o}\ 12'\ 22'' \pm 6''$$

and the value of the unit of co-ordinates in British inches is

.00508259 ± .00000003 log. .7060853 ± .0000017

or the number of units in the inch

196.750 ± .001 log. .2939147 ± .0000017

TABLE OF CO-ORDINATES OF MARKED STATIONS

Place.	Letter.	From North.	From East.
S.W. corner of the 9th Pyramid	A	3 987 140	0 935 234
N. side of 2nd Pyramid Temple	B	5 393 798	3 411 980
N. side of 3rd Pyramid Temple	C	8 382 255	5 839 239
Top block of 5th Pyramid	D	9 143 054	6 836 560
N. side of 3rd Pyramid	E	8 072 225	6 840 249
Rock of hill, W. of 1st Pyramid	F	4 246 813	8 132 966
Tomb, No.17, Lepsius	G	3 000 000	6 000 000
Hillock S.E. of 3rd Pyramid	H	10 092 621	5 571 047
Top of large building E. of 3rd Pyramid	J	7 828 554	1 491 863
Pile of slabs N.E. of 1st Pyramid	K	1 300 292	1 425 399
Slab in ground N. of entrance of 1st Pyramid (Gill)	L	0 908 159	2 242 158
Tomb N.W. of N.W. corner of 1st Pyramid	M	1 483 587	3 431 388
Tomb W. of N.W. corner of 1st Pyramid (Gill)	N	1 848 869	4 136 068
N.W. socket of of 1st Pyramid (Gill)	O	1 844 679	3 173 572
Edge of floor of passage of 1st Pyramid	P	1 993 386	2 221 893
N.E. socket of of 1st Pyramid (Gill)	Q	1 880 871	1 381 354
Staff on top of 1st Pyramid	R	2 756 484	2 298 662
W. side of 7th Pyramid	S	3 007 571	0 915 729
E. side rubbish heap of 1st Pyramid (Gill)	T	2 706 202	1 477 899
S.E. socket of 1st Pyramid (Gill)	U	3 672 518	1 417 048

S. side on masonry of 1st Pyramid	V	3 523 071	2 369 777
S.W. socket of 1st Pyramid	W	3 634 188	3 206 895
W. side rubbish heap of of 1st Pyramid (Gill)	X	2 745 956	3 073 389
Tomb) No.44, Lepsius of 1st Pyramid (Gill)	Y	2 926 171	3 863 947
E. end of base line, on block of basalt	Z	4 415 043	1 704 140
W. end of base line, on block of basalt	a	4 306 415	3 255 538
Masonry above, and W. of, door, 2nd Pyramid	b	4 732 762	4 900 971
N.W. corner of rock cutting round 2nd Pyramid	g	4 146 945	5 968 245
N.W. corner 2nd Pyramid	d	4 592 901	5 758 968
N.E. corner 2nd Pyramid	e	4 632 817	4 092 173
S.E. corner (on masonry) 2nd Pyramid	z	6 251 313	4 157 284
S.W. corner 2nd Pyramid	h	6 262 182	5 785 021
W. side of rock cutting round 2nd Pyramid	q	5 950 148	6 000 994
Wall W. of 3rd Pyramid	i	7 563 291	8 109 839
N. side of 4th Pyramid	k	9 054 182	7 586 701
N.W. corner of masonry of 3rd Pyramid	l	8 035 816	7 200 134
S.VV. corner of masonry of 3rd Pyramid	m	8 761 575	7 230 130
S.E. corner of masonry of 3rd Pyramid	n	8 786 405	6 488 386
N.E. corner of masonry of 3rd Pyramid	x	8 038 069	6 485 183
Masonry below door, 1st Pyramid	p	1 935 512	2 249 041
N.end of North Trench	r	2 082 608	1 180 207
S.end of North Trench	s	2 514 650?	1 175 360?
N. end of South Trench	t	3 051 826	1 184 632
S. end of South Trench	u	3 463 988	1 180 826
W.end of E.N.E. Trench	j	2 678 581	0 881 168
E. end of E.N.E. Trench	c	2 648 862	0 568 721
S. end of Trial passages	y	2 549 708	0 721 984
N. end of Trial passages	w	2 350 481	0 718 038

RESULTING CO-ORDINATES OF POINTS OF ANCIENT CONSTRUCTION.

Existing casing edge on N. side of 1st pyramid	1 866 612	2 281 355
Existing casing edge on E. side of 1st pyramid	2 671 090	1 401 430
Existing casing edge on S. side of 1st pyramid	3 646 300	2 515 643
Existing casing edge on W. side of 1st pyramid	2 664 836	3 185 923
N.E corner of casing of side of 1st pyramid	1 884 598	1 385 776
S.E corner of casing of side of 1st pyramid	3 668 168	1 421 276
S.W corner of casing of side of 1st pyramid	3 632 521	3 205 195
N.W corner of casing of side of 1st pyramid	1 848 772	3 169 668
Center of casing side of 1st pyramid	2 758 515	2 295 478
N.E. corner of casing of 2nd pyramid	4 630 771	4 089 656
S.E. corner of casing of 2nd pyramid	6 297 958	4 121 664
S.W. corner of casing of 2nd pyramid	6 265 598	5 789 181
N.W. corner of casing of 2nd pyramid	4 598 359	5 756 193
Center of casing side of 2nd pyramid	5 448 171	4 939 173
N.E. corner of casing of 3rd pyramid	7 998 215	6 437 758
S.E. corner of casing of 3rd pyramid	8 814 325	6 457 924
S.W. corner of casing of 3rd pyramid	8 793 987	7 275 727
N.W. corner of casing of 3rd pyramid	7 976 980	7 255 560?
Center of casing side of 3rd pyramid	8 395 877	6 856 742

20. The materials available for a discussion of the original size of the base of the Great pyramid are:--

(1) the casing in situ upon the pavement, in the middle of each face;
(2) the rock cut sockets at each corner;
(3) the levels of the pavement and sockets;
(4) the mean planes of the present core masonary.

Since the time of the first discovery of some of the sockets in 1801, it has always been supposed that they defined the original extent of the Pyramid, and various observers have measured from corner to corner of them, and thereby obtained a dimension which was---without further inquiry---put down as the length of the base of the Pyramid. But, inasmuch as the sockets are on different levels, it was assumed that the faces of the stones placed in them rose up vertically from the edge of the bottom, until they reached the pavement (what-ever level that might be) from which the sloping face started upwards. Hence it was concluded that the distances of the socket corners were equal to the lengths of the Pyramid sides upon the pavement

Therefore, when reducing my observations, after the first winter, I found that the casing on the North side (the only site of it then known) lay about 30 inches inside the line joining the sockets, I searched again and again for any flaw in the calculations. But there were certain check measures, beside the regular checked triangulation, which agreed in the same story; another clue, however, explained it, as we shall see.

The form of the present rough core masonry of the Pyramid is capable of being very closely estimated. By looking across a face of the Pyramid, either up an edge, across the middle of the face, or even along near the base, the mean optical plane which would touch the most prominent points of all the stones, may be found with an average variation at different times of only 1.0 inch. I therefore carefully fixed, by nine observations at each corner of each face, where the mean plane of each face would fall on the socket floors; using a straight rod as a guide to the eye in estimating. On reducing these observations to give the mean form of the core planes at the pavement level, it came out thus :---

	Case Plane Sides.	Azimuths.	Socket Sides.	Azimuths.
N.	9002.3	– 4' 35"	9129.8	– 3' 20"
E.	8999.4	– 5' 26"	9130.8	– 5' 21"
S.	9001.7	– 5' 23"	9123.9	+ 1' 15"
W.	9002.5	– 5' 39"	9119.2	– 7' 33"
Mean	9001.5	– 5' 16"	9125.9	– 3' 45"
Mean Difference	1.0	20"	4.4	2' 42"

Here, then, was another apparently unaccountable fact, namely, that the core masonry was far more accurate in its form than the socket square. It is, in fact, four times as accurate in length, and eight times as accurate in angle. This forced me to the conclusion that the socket lines cannot show the finished base of the Pyramid.

The clue which explains all these difficulties is ---that the socket corners vary from a true square in proportion to their depth below the pavement, the sockets nearer the centre being higher.

This means that the sockets were cut to receive the foot of the sloping face, which was continued right down to their floors, beneath the pavement. (See Pl. xi.)

Hence the sockets only show the size of the Pyramid, where it was started from varying levels, which were all under the pavement; and its true base upon the pavement is therefore 20 or 30 inches inside the lines of the sockets.

This exactly explains the position of the casing found on the N. side, as it was found to be inside the line of the sockets.

The test, then, of this explanation, was to find the casing on the other sides, fix its position, and see if it was likewise within the lines of the sockets. The shafts were accordingly sunk through the rubbish, two or three feet inside the socket lines; and the casing was found on each side, just in the expected alignment. Without this clue, the narrow shafts might easily have missed the casing altogether, by being sunk too far out from the Pyramid.

Now having found the casing foot on each side of the Pyramid, it is settled that the faces must have passed through these fixed points, and when the casing was duly projected down at its angle of slope to the socket floors, it was found to fall on an average 4 inches inside the edges of the socket corners. This is what might be expected, as the socket sides are neither straight nor square; so that this margin would be much less at a minimum than it is at their corners; and it would be natural to allow some free space, in which to adjust the stone.

21. Having, then, four lines passing through the middles of the sides, what is to define the junctions of those lines at the corners ? Or, in other words, what defines their azimuth? Was each side made equidistant (1) from its socket's sides ? or, (2) from the core side at each of its ends ? Or was a corner made equidistant (3) from the sides of its socket corner? or, (4) from the sides of its core corner? The core may be put out of the question ; for if the sides followed it exactly in any way, they would run outside of the sockets in some parts. Which, then, is most likely: that the sockets were placed with an equal amount of margin allowed on the two ends of one side, or with an equal margin allowed at both sides of one corner? The latter, certainly, is most likely; it would be too strange to allow, say, 6 inches margin on one side of a socket, and only 2 inches on its adjacent side. It seems, then, that we are shut up to the idea that the socket corners lie in the diagonals of the Pyramid casing.

But there is another test of this arrangement, which it ought to satisfy. Given four diagonals, as defined by the socket corners; and given four points near the middles of the sides of the Pyramid, as defined by the existing casing: if we start from one diagonal, say N.E.; draw a line through the E. casing to S.E. diagonal; from that through the S. casing, to the S.W. diagonal; and so on, round to the N.E. diagonal again ; there is no necessity that the line should on its return fall on the same point as that from which we started : it might as easily, apart from special design, fall by chance anywhere else. The chances are greatly against its exactly completing its circuit thus, unless it was so planned before by the diagonals of the socket corners being identical with those of the square of the casing.

On applying this test to the diagonals of the sockets, we find that the circuit unites, on being carried round through these points, to within 1 inch far closer, in fact, than the diagonals of the sockets and the line of the casing can be estimated.

This is, then, a conclusive test; and we only need to compute a square that shall pass through the points of the casing found on each side, and having also its corners lying on the diagonals of the sockets. This square, of the original base of the Great Pyramid casing on the platform, is of these dimensions :---

	Length.	Difference from Mean.	Azimuth.	Difference from Mean.
N	9069.4	+ .6	– 3' 20"	+ 23"
E	9067.7	– 1.1	– 3' 57"	– 14"
S	9069.5	+ .7	– 3' 41"	+ 2"
W	9068.6	– .2	– 3' 54"	– 11"
Mean	9068.8	.65	– 3' 43"	12"

Thus the finished base of the Pyramid had only two-thirds of the irregularity of the core masonry, the mean difference of which was 1.0 inch and 20" ; this is what would be expected from a final adjustment of the work, after the rougher part was finished.

But it must always be remembered that this very small mean error of .65 inch and I2" is that of the sockets, and not that of the casing stones; these latter we can hardly doubt would be adjusted more carefully than the cutting of the sockets with their free margin.

Also it must be remembered that this result includes the errors of survey. Now the probable errors of fixing the plumb-lines in the triangulation were about .2 on E. side, .2 on S. side, .1 on W. side, and the casing .1 on N. side; the probable errors of the triangulation of the points of reference is in general much less than this; we may then say ±.3 for the absolute places of the plumb-lines. The exact amount of this is not of so much ccontinuequence, because the errors of estimating the original points of construction are larger. They are, on the N., ±.04; on the E., ±.02 ; but another less satisfactory estimate differed 1.1 on the S., ±.02; on the W., ±.05, taking the mean of two points that differed 1.1 inches. Besides this, the estimation of the socket diagonals cannot be put under ±.5 by the bad definition of the edges and want of straightness and orientation of the sides. If we then allow that the probable errors from all sources of our knowledge, of each of the original sides of the Pyramid amount to ±.6, we shall not over-estimate them. Hence it is scarcely to be expected that our determinations of the sides should agree closer than .65 inch, as they do on an average.

So we must say that the mean errors of the base of the Great Pyramid were somewhat less than .6 inch, and 12" of angle.

22. In computing the above quantities, I have used my final determination of the socket levels below the pavement; these, with the first approximate results, and Inglis's figures, stand thus ;--

	Accurate in 1882	Approx in 1881	Inglis in 1865
N.E.	– 28.5	– 28.7	– 28.6
S.E.	– 39.9	– 39.9	– 42.4
S.W.	– 23.0	– 22.9	– 23.0
N.W.	– 32.8	– 32.6	– 32.8

the level of the pavement being zero. The approximation was very roughly done, and it is strange that it should agree as well with the accurate determination as it does. From Inglis's measures I have subtracted 28.6, in order to reckon them from the pavement level; by the exact agreement of my two levellings at the S.E. (which was taken second in the series each time, and hence is checked by others), I conclude that Inglis is there in error by a couple of inches; and his other work, in measuring the steps, contains much larger errors than this.

The relations, then, of the core masonry, the base of the casing on the pavement, the edge of the casing in the sockets, and the socket edges, are shown in Pl. x., to a scale of 1/50. The position of the station marks is also entered. The inclinations of the various sides of sockets and casing are stated; and it is noticeable that the core masonry has a twist in the same direction on each side, showing that the orientation of the Pyramid was slightly altered between fixing the sockets and the core. The mean skew of the core to the base is 1' 33", and its mean azimuth -- 5' 16" to true North. The diagram also shows graphically how much deformed is the square of the socket lines ; and how the highest socket (S.W.) is nearest to the centre of the Pyramid ; and the lowest socket (S.E.) is furthest out from the centre of the socket diagonals, and also from the mean planes of the core.

23. For ascertaining the height of the Pyramid, we have accurate levels of the courses up the N.E. and S.W. corners; and also hand measurements up all four corners. The levels were all read to 1/100 inch, to avoid cumulative errors; but in stating them in Pl. viii., I have not entered more than tenths of an inch, having due regard to the irregularities of the surfaces.* The discrepancy of .2 inch in the chain of levels (carried from the N.E. to S.E., to S.W., on the ground, thence to the top, across top, and down to N.E. again), I have put all together at the junction of levelling at the 2nd course of the S.W., as I considered that the least certain point. It may very likely, however, be distributed throughout the whole chain, as it only amounts to I.8" on the whole run.

* Owing to mistaking (in a photograph) the rock bed of the pavement for the pavement itself, Prof. Smyth has entered all the levels in his works (both of his own measures and those of others) from a datum 20 inches below the true pavement level. This has led him to reckon the first course as two; hence all his course numbers must have one subtracted, and all his levels about 20 inches subtracted, to reduce them to a true start from the pavement surface.

These levels, though important for the heights of particular courses, have scarcely any bearing on the question of the total height of the original peak of the casing of the pyramid; because we have no certain knowledge of the thickness of the casing on the upper parts.

The zero of levels that I have adopted, is a considerable flat-dressed surface of rock at the N.E. corner, which is evidently intended to be at the level of the pavement; it has the advantage of being always accessible, and almost indestructible. From this the levels around the Pyramid stand thus :---

	N.E.	E.	S.E.	S.	S.W	W.	W.N.W.	N.W.	N.
2nd Course	+ 107.7		+ 105.5		+111.2			+106.6	+107.4
1st Course	+ 58.6				+ 57.6			+ 58.0	+ 58.9
Levelled [	0	E.N.E.							
rock [	– .15	N.N.E.							
Pavement		– .6?		– 5.5?		+ 1.1?	– 1.2?		+.
Socket	– 28.5		– 39.9		– 23.0			– 32.8	

The pavement levels, excepting that on the N. side below the entrance, are not of the same accuracy as the other quantities; they were taken without an assistant, merely for the purpose of showing that it really was the pavement on which the casing was found to rest on each side. The differences of the 1st course levels, probably show most truly the real errors of level of the base of the Pyramid.

24. To obtain the original height of the Pyramid, we must depend on the observations of its angle. For this there are several data, as follows; the method by which the passage and air channels determine it being explained in detail further on, when the internal parts are discussed :--

Casing stones, in situ, N. side, by theodolite	**51° 46' 45"**	**± 2' 7"**	**weight 7**
(To 3 points on top and 3 on base.) by goniometer and level	51° 49'	1'	2
(To 3 points on top and 3 on base.) by steel square and level	51° 44' 11"	23"	0
(To 3 points on top and 3 on base.) 5 overthrown by goniometer	51° 52'	2'	0
(To 3 points on top and 3 on base.) 18 fragments, all sides, goniometer (All above 2 inches in shortest length)	51° 53'	4'	0
N. face, by entrance passage mouth	51° 53' 20"	1'	10
N. face, by air channel mouth	51° 51' 30"	20"	5
N. face, weighted mean	51° 50' 40"	1' 5"	
S. face by air channel mouth	51° 57' 30"	20"	

In assigning the weights to these different data, the reason that no weight is given to the angles of shifted casing stones is that there is no proof that the courses did not dip inwards somewhat; on the contrary, I continually observed that the courses of the core had dips of as much as ½° to 1° so that it is not at all certain that the courses of the casing were truly level to 5' or 10', and occasional specimens showed angles up to 54°. The angle by means of the large steel square was vitiated by the concretion on the faces of the stones being thicker below than above, .1 inch of difference making an error of 6'. The small goniometer was applied to the clear patches of the stone, selected in nine different parts. These three casing stones in situ have not as much weight assigned to them as they would otherwise have, owing to their irregularities. One of them is 0.9 in front of the other at the top, though flush at the base ---a difference of 4'. The datum from the air channel, though far more accurate than that by the passage mouth (being on a longer length), is not so certainly intentional, and is therefore not worth as much. (See sections 32 and 33 for details.) From all these considerations the above weighting was adopted. It is clear that the South face should not be included with the North, in taking the mean, as we have no guarantee that the Pyramid was equiangular, and vertical in its axis.

25. The staff which was set up by the Transit of Venus party in 1874 on the top of the Pyramid, was included in my triangulation; and its place is known within ± ½ inch. From this staff, the distances to the mean planes of the core masonry of the Pyramid sides, were determined by sighting over their prominent edges, just as the positions of the mean planes were fixed at the lower corners of the faces. Hence we know the relation of the present top of the core masonry to the base of the Pyramid. The top is, rather strangely, not square, although it is so near to the original apex. This was verified carefully by an entire measurement as follows :--

			Mean of four readings, 1881.	Mean of three readings, 1882.	Mean of all.
Center of Pyramid base horizontal to the :	[	N. side E. side S. side W. side	226.0 ± .5 214.4 ± .4 215.0 ± .6 216.4 ± .5	223.7 ± .2 213.8 ± .6 215.0 ± .4 218.7 ± .5	224.5 ± .7 214.1 ± .3 215.0 ± .4 217.6 ± 1.0

Now, at the level of these measurements, 5407.9 at N.E., or 5409.2 at S.W., above the base, the edges of the casing (by the angles of the N. and S. side found above) will be 285.3 ± 2.7 on the North, and 30I.6 on the South side, from the vertical axis of the centre. Thus there would remain for the casing thickness 60.8 ± 3 on the N., and 86.6 on the S.; with 77.6 for the mean of E. and W. Or, if the angle on the S. side were the same as on the N., the casing thickness would be 69.2 on the S. This, therefore, seems to make it more likely that the South side had about the same angle as the North.

On the whole, we probably cannot do better than take **51° 52' ± 2'** as the nearest approximation to the mean angle of the Pyramid, allowing some weight to the South side.

The mean base being **9068.8 ± .5 inches**, this yields a height of **5776.0 ± 7.0 inches.**

26. With regard to the casing, at the top it must---by the above data---average about 71 ± 5 inches in thickness from the back to the top edge of each stone. Now the remaining casing stones on the N. base are of an unusual height, and therefore we may expect that their thickness on the top would be rather less, and on the bottom rather more, than the mean of all. Their top thickness averages 62 ± 8 (the bottom being 108 ± 8), and it thus agrees very fairly with 71 ± 5 inches. At the corners, however, the casing was thinner, averaging but 33.7 (difference of core plane and casing on pavement); and this is explained by the faces of the core masonry being very distinctly hollowed.

This hollowing is a striking feature; and beside the general curve of the face, each side has a sort of groove specially down the middle of the face, showing that there must have been a sudden increase of the casing thickness down the mid-line. The whole of the hollowing was estimated at 37 on the N. face; and adding this to the casing thickness at the corners, we have 70.7, which just agrees with the result from the top (71 ± 5), and the remaining stones (62 ± 8). The object of such an extra thickness down the mid-line of each face might be to put a specially fine line of casing, carefully adjusted to the required angle on each side ; and then afterwards setting all the remainder by reference to that line and the base.

Several measures were taken of the thickness of the joints of the casing stones. The eastern joint of the northern casing stones is on the top .020, .002, .045 wide; and on the face .012, .022, .013, and .040 wide. The next joint is on the face .011 and .014 wide. Hence the mean thickness of the joints there is .020; and, therefore, the mean variation of the cutting of the stone from a straight line and from a true square, is but .01 on length of 75 inches up the face, an amount of accuracy equal to most modern opticians' straight-edges of such a length. These joints, with an area of some 35 square feet each, were not only worked as finely as this, but cemented throughout. Though the stones were brought as close as 1/500 inch, or, in fact, into contact, and the mean opening of the joint was but 1/50 inch, yet the builders managed to fill the joint with cement, despite the great area of it, and the weight of the stone to be moved-some 16 tons. To merely place such stones in exact contact at the sides would be careful work; but to do so with cement in the joint seems almost impossible

The casing is remarkably well levelled at the base ; the readings on the stones of the North side, and the pavement by them being thus :--

	W.End.	Middle.	E.End.	Pavement by casing.	Core 40ft.E. of casing.
Casing Front	+ 58.83	+ 58.84	+ 58.90	– .01	
Casing Back	+ 58.84		+ 58.85	– .03	
Core				+ .02	+ 58.87
Pavement	(–.56)	(–.30)	(–.05)	.00	

The pavement levels in brackets are on decidedly worn parts, and hence below the normal level, as shown in the fourth column. The average variation of the casing from a level plane of + 58.85 is but .02; and the difference to the core level, at the farthest part accessible in that excavation, does not exceed this. The difference of pavement level out to the rock at the N.E. corner is but .17 on a distance of 4,200 inches, or 8" of angle.

27. The works around the Pyramid, that are connected with it, are :--
(1) The limestone pavement surrounding it; (2) the basalt pavement on the E. side and (3) the rock trenches and cuttings on the E. side, and at the N.E. corner.

The limestone pavement was found on the N. side first by Howard Vyse, having a maximum remaining width of 402 inches; but the edge of this part is broken and irregular, and there is mortar on the rock beyond it, showing that it has extended further. On examination I found the edge of the rock-cut bed in which it was laid, and was able to trace it in many parts. At no part has the paving been found complete up to the edge of its bed or socket, and it is not certain, therefore, how closely it fitted into it ; perhaps there was a margin, as around the casing stones in the corner sockets. The distances of the edge of this rock-cut bed, from the edge of the finished casing on the pavement (square of 9068.8) were fixed by triangulation as follows :--

N.N.W.	616.9 near the corner; corner itself not found, nor any W.N.W. side.
	615.9 at 570 E. of probable N.W. corner of pavement.
	618.7 at 670 E.
	616.2 at 890 E.
N.side	564 to 568 very rough and irregular, opposite entrance.
N.N.E.	529.0 at N.E. corner, N. side of it.
E.N.E.	538.8 at N.E. corner, E. side of it.
	533.9 at 586 from N.E. corner.
	No cutting found at S.E. corner.
	536.5 at 846 from S.W. corner.
	533.0 at 520 from S.W. corner.
	534.6 at 206 from S.W. corner.
S.S.W.	529.6 at S.W. corner, S. side of it.
W.S.W.	536.0 at S.W. corner, W. side of it.
	627.9 at 751 from S.W. corner.

From these measures it appears that there is no regularity in the width of the cutting; the distance from the casing varying 99 inches, and altering rapidly even on a single side. The fine paving may possibly have been regular, with a filling of rougher stone beyond it in parts; but if so, it cannot have exceeded 529 in width.

The levels of the various works around the Pyramid are as follow, taken from the pavement as zero :--

Flat rock-bed of pavement W. of N.W. socket	– 23.7
Flat rock-bed of pavement beside N.W. socket	– 21.6
Flat rock-bed of pavement N. of N.W. socket	– 17.0
Flat rock-bed of pavement N.E. of N.W. socket	– 15.9
Flat rock-bed of pavement before entrance	– 27.1
Flat rock-bed of pavement inner end of E.N.E. trench	– 26.9
Basalt pavement, E. side of it	+ 2.0
Basalt pavement, W. side, in excavation	+ 2.0

The Pyramid pavement must then have varied from 17 to 27 inches in thickness; it was measured as 21 inches where found by Vyse.

28. The basalt pavement is a magnificent work, which covered more than a third of an acre. The blocks of basalt are all sawn and fitted together; they are laid upon a bed of limestone, which is of such a fine quality that the Arabs lately destroyed a large part of the work to extract the limestone for burning. I was assured that the limestone invariably occurs under every block, even though in only a thin layer. Only about a quarter of this pavement remains in situ, and none of it around the edges the position of it can therefore only be settled by the edge of the rock-cut bed of it. This bed was traced by excavating around its N., E., and S. sides; but on the inner side, next to the Pyramid, no edge could be found ; and considering how near it approached to the normal edge of the limestone pavement, and that it is within two inches of the same level as that, it seems most probable that it joined it, and hence the lack of any termination of its bed.

Referring, then, to the E. side of the Pyramid, and a central line at right angles to that (see Pl. ii.), the dimensions of the rock bed of the basalt paving are thus :--

NORTH TO SOUTH.

From mid-line of Pyramid	1046.0 to N.E.	1061.9 to N.W.
	1077.7 to S.E.	1062.8 to S.W.
Total length	2123.7 E. side.	2124.7 W. side.
S. corner of opening on E. side	321.0 to mid.	756.7 to S.E.
N. corner of opening on E. side	693.3 to mid.	352.7 to N.E.

EAST TO WEST.

Width traced.	1006.6 + ×.
E. side, from Pyramid base.	2153.0 N. end.
	2148.0 S. end.
S. corner of opening on E. side of the base.	2169.0
N. corner of opening on E. side of the base.	2160.0

Next, referring this pavement to the trench lines :--

NORTH TO SOUTH.

N. trench, inner end from basalt	318.1
S. trench, inner end from basalt	327.9

EAST TO WEST.

N.E. corner to N. trench axis	1073.2
N. trench axis there, to Pyramid	1079.8
S.E. corner to S. trench axis	1022.6
S. trench axis there, to Pyramid	1125.8
S.E. corner to N. trench axis, continued	1075.0
N. trench axis there, to Pyramid	1073.0

Hence the plan of the basalt pavement seems to be two adjacent squares of about 1,060 inches in the side; the N. trench axis being the boundary of them, and there being a similar distance between that and the Pyramid. The outer side of the paving was laid off tolerably parallel to the Pyramid base ; but the angles are bad, running 15 inches skew.*

* The broken blocks of basalt, which border a track down the hill side E. of them Pyramid, are almost certainly from this pavement; they are of exactly the same stone, and have many worked faces remaining like those of the pavement. Their placing is quite rude, and looks as if done by some barbarian destroyers.

29. Next, referring to the rock-hewn trenches alone, the dimensions of the three deep ones are as follow :--

NORTH TO SOUTH.

N. trench, outer end, to central line	3510.2
N. trench, axial length	2130.2
N. trench, inner end, to central line	1380.0
S. trench, inner end, to central line	1390.7
S. trench, axial length	2093.7
S. trench, outer end, to central line	3430.4
E.N.E. trench, outer end of axis N. of central line	848.3
E.N.E. trench, axis cuts N. trench axis N. of central line	68.5

EAST TO WEST.

N. trench axis, outer end to base	1085.5
N. trench axis, inner end to base	1080.6
S. trench axis, inner end to base	1125.5
S. trench axis, outer end to base	1122.9
S. trench axis, E. of N. trench axis, at centre	497
E.N.E. trench, outer end of axis to base	4213.2
E.N.E. trench, axial length from N. trench axis	3231.1
E.N.E. trench, axial length from actual bed of basalt	2112.6
E.N.E. trench, axial length from straight edge	2124.7

The slighter trenches are three in number :--

NORTH TO SOUTH.

N.N.E. trench axis cuts N. trench axis N. of central line	116.0
Trench by N.E. socket, end of axis from N. side of casing	643.3
Trench by N.E. socket, on the axis, from N. side of casing	1630.8
Trench by trial passages, ends of axis N. of central line	1563.3
	1274.4

EAST TO WEST.

N.N.E. trench, axis cuts pavement, from N.E. corner	647.2
Trench by N.E. socket, end of axis from E. side of casing	203.2
Trench by N.E. socket, on the axis, from E. side of casing	434.1
Trench by trial passages, ends of axis E. of Pyramid base	3161.6
	3167.6

The subterranean passages are in one group :--

NORTH TO SOUTH.

Trial passages axis, N. of central line, at the station marks	[2233.6
	1220.8

EAST TO WEST.

Trial passages axis, E. of central line, at the station marks	[3446.7
	3441.2

Hence it seems that the axial length of the E.N.E. trench outside the basalt paving is intended to be the same as the axial length of the North and South trenches.

The angles of the axes of these trenches are as follow :--

	To E. Face of Pyramid.	To true North.
N. trench	+ 7' 53"	+ 3' 56"
S. trench	+ 4' 09"	+ 12"
E.N.E. trench	+ 76º 02' 26"	+ 75º 58' 23"
N.N.E. trench	+ 24º 25' 34"	+ 24º 21' 37"
Trench by N.E. socket	+ 13º 09' 38"	+13º 5' 41"
Trench by trial passages	– 1º 11'	– 1º 15'
Trial passages	+ 18' 40"	+ 14' 43"

Thus the angles between the trenches are: S. trench to E.N.E. trench, 104º I' 43" (or 2 X 52º 0' 52"); and E.N.E. to N.N.E. trench, 51º 36' 52."

With regard to the details of these rock cuttings, the forms of the ends of the N. and S. trenches were plotted from accurate offsets (see P1. iiia.); and there is little of exact detail in the cutting to be stated. The axes at the ends were estimated by means of the plans here given, but on double this scale; and the rock is so roughly cut in most parts that nothing nearer than an inch need be considered. The position of the inner end of the N. trench is not very exactly fixed, an omission in measurement affecting it, mainly from N. to S. In this trench I excavated to 110 below the present surface of the sand, or about 220 below the rock surface, without finding any bottom. The S. trench is more regular than the N. trench; at the outer end its width is 205 to 206, and at the inner end 134.2: it has a curious ledge around the inner end at 25 below the top surface. At the outer end the rock is cut, clearly to receive stones, and some plaster remains there; also some stones remain fitted in the rock on the W. side of this trench. Built stones also occur in the N., E.N.E., and N.N.E. trenches. From the inner end of the S. trench, a narrow groove is cut in the rock, leading into the rock-cut bed of the basalt pavement; this groove was filled for a short way near the end of the trench by stone mortared in. It was evidently in process of being cut, as the hollows in the sides of it were the regular course of rock-cutting. The rock beside the trenches is dressed flat, particularly on the E. of the N. trench, and the W. of the S. trench, where the built stones occur. There is a short sort of trench, on the E. side of the S. trench (not in plan); it is about 25 wide, 70 long, and 50 deep, with a rounded bottom; the length E. and W.

The E.N.E. trench is very different to the others; it has a broad ledge at the outer end, and this ledge runs along the sides of the trench, dipping downwards until it reaches the bottom towards the inner end: the bottom sloping upwards to the surface at the inner end. There are stones let into this ledge, and mortared in place, and marks of many other stones with mortared beds, all intended apparently to make good the ledge as a smooth bed for some construction to lie upon. The bottom of this trench I traced all over, by excavations across and along it; looking from the outer end, there first came two ledges-the lower one merely a remainder of uncut rock, with grooves left for quarrying it-then the bottom was found about 200 inches below ground level; from this it sloped down at about 20º for about 200 inches; then ran flat for 300 or 400; and then sloped up for 300 or 400; then rose vertically, for some way; and then, from about 120 below ground level, it went up a uniform slope to near the surface, where it was lost at the inner end under high heaps of chips. At the outer end the width near the top is 152.8, and at 25 down 148.2 ; the lower space between the sides of the ledge widens rapidly to the middle, from the end where it is 43.0 wide above and 35.0 below. Towards the inner end the rock is very well cut; it has a row of very rough holes, about 6 diam., in the dressed rock along the N. edge of the trench, near the inner end. This dressed side of the trench ends sharply, turning to N. at 1603.6 from outer end of the trench axis; the width here is 170.I, or 172.3 at a small step back in S. side, a little E. of this point. The trench had not been clear for a long time, as many rudely-buried common mummies were cut through in clearing it; they were lying only just beneath the sand and rubbish in the bottom.

The N.N.E. trench was traced by excavations along the whole length of 2,840 inches, up to where it is covered by the enclosure wall of the kiosk. It is fairly straight, varying from the mean axis 2.1, on an average of five points fixed along it. The depth varies from 14 to 20 inches below the general surface. It is 38, 40, 39.2, and 36 in width, from the outer end up to a point 740 along it from the basalt pavement; here it contracts roughly and irregularly, and reaches a narrow part 18.2 wide at 644 from the pavement. The sides are built about here, and deeply covered with broken stones. Hence it runs on, till, close to the edge of the basalt pavement, it branches in two, and narrows yet more; one line runs W., and another turning nearly due S., emerges on the pavement edge at 629.8 to 633.4 from the N.E. corner of the pavement, being there only 3.6 wide. From this remarkable forking, it is evident that the trench cannot have been made with any ideas of sighting along it, or of its marking out a direction or azimuth; and, starting as it does, from the basalt pavement (or from any building which stood there), and running with a steady fall to the nearest point of the cliff edge, it seems exactly as if intended for a drain; the more so as there is plainly a good deal of water-weanng at a point where it falls sharply, at its enlargement. The forking of the inner end is not cut in the rock, but in a large block of limestone.

The trench by the N.E. socket is just like the N.N.E. trench in its cutting and size; and it also narrows at the inner end, though only for about 20 inches length. It has a steady fall like the N.N.E. trench; falling from the S. end 5.5 at 50, 8.5 at 100, 14.3 at 190, 21.0 at 300, and 27.0 at 400 inches. The inner end is turned parallel to the Pyramid, the sides curving slightly to fit it.

The rock cuttings by it are evidently the half-finished remains of a general dressing down of the rock; the hollows are from 3 to 6 inches deep, and so very irregular that they do not need any description beside the plan (P1. ii.).

The trench beside the trial passages is slight, being but 6 deep at N. and 17 at S.; it is 29.0 wide at N., 26.5 in middle, and 27.9 at S. Its length is 289, with square ends. The sides are vertical at the N., narrowing 3.5 to bottom at S.; ends shortening 3.0 to bottom. The bottom dips slightly to the S., the levels from the N. running 0, -- 1.7, -- 2.2, -- 3.2, arid -- 5.8.

30. The trial passages P1. iii b. are a wholly different class of works to the preceding, being a model of the Great Pyramid passages, shortened in length, but of full size in width and height. Their mean dimensions -and mean differences from those dimensions- as against the similar parts of the Great Pyramid, are:--

26º 32' mean difference .24'	Pyramid passage angle 26º 27' mean diff. 4'
41.46 mean difference .09	Pyramid passage widths 41.53 mean diff. .07
47.37 mean difference .13	Pyramid passage heights 47.24 mean diff. .05
23.60 mean difference .08	Pyramid ramp heights 23.86 mean diff. .32
81.2 mean difference .6	Pyramid gallery widths 82.42 mean diff. .44
28.63 mean difference .54	Pyramid well widths 28.2 mean diff. .3

The details of the measurements of each part are all entered on the section (P1. iiib.). The vertical shaft here is only analogous in size, and not in position, to the well in the Pyramid gallery; and it is the only feature which is not an exact copy of the Great Pyramid passages, as far as we know them. The resemblance in all other respects is striking, even around the beginning of the Queen's Chamber passage, and at the contraction to hold the plug-blocks in the ascending passage of the Pyramid (see section 38). The upper part of the vertical shaft is filled with hardened stone chips; but on clearing the ground over it, I found the square mouth on the surface. The whole of these passages are very smoothly and truly cut, the mean differences in the dimensions being but little more than in the finely finished Pyramid masonry. The part similar to the gallery is the worst executed part ; and in no place are the corners worked quite sharp, generally being left with radius about .15. The N. end is cut in steps for fitting masonry on to it; and I was told that it was as recently as 1877 that the built part of it was broken away by Arabs, and it appeared to have been recently disturbed ; in Vyse's section, however, the roof is of the present length, so the removal must have been from the floor. By theodolite observations the plane of the passage is straight and vertical within 5' or less.

31. Having thus finished the statement of the outside of the Pyramid and the works surrounding it, the next subject is the connection of the outside and inside of the building.

To determine the exact place of the passages and chambers in relation to the whole Pyramid, a station of the triangulation was fixed in a hollow just on the end of the entrance passage floor and this was thoroughly connected with three main stations. Levelling was also carried up from the casing and pavement below, to this station, and to the courses near it. Thus the inside, as far as Mamun's Hole, is completely connected with the outside; and in the ascending passages beyond that, there is only 2' of azimuth in doubt.

32. The original length of the entrance passage has not hitherto been known, except by a rough allowance for the lost casing. But after seeing the entrances of the Third Pyramid, the South Pyramid of Dahshur, and the Pyramid of Medum, all of which retain their casing, there seemed scarcely a question but that the rule was for the doorway of a Pyramid to occupy the height of exactly one or two courses on the outside. That the casing courses were on the same levels as the present core courses, is not to be doubted, as they are so in the other Pyramids which retain their casing, and at the foot of the Great pyramid *

* The awkward restoration of the casing that Prof, Smyth adopted (Life and Work, P1. iii., 3) was forced on him by his mistaken assumption of the pavement level 20 inches under the truth (L. and W. ii. 137); hence by Vyse's casing stone measures he made the casing break joint with the core, in defiance of Vyse's explicit drawing of its position; and was obliged to reduce the pavement to 5 or 10 inches, in place of the 21 inches recorded by Vyse. The drawing of "hacking stones," at the foot of P1. 1., vol. iii., L. and W., is equally at fault; the casing stones which remain in the middle of the side, ending directly against the core masonry; and the core at the corners only leaving 34 inches for the casing thickness, No backing stones exist behind the casing of the Third Pyramid or the cased Dahshur Pyramid.

The next step is to see if there is a course equal to the vertical height of the doorway; and, if so, where such a course occurs. Now the vertical height of the doorway on the sloping face of the Pyramid (or difference of level of its top and base) would be 37.95 if the passage mouth was the same height as the present end, or 37.78 if the passage was exactly the same as the very carefully wrought courses of the King's Chamber, with which it is clearly intended to be identical. On looking to the diagram of courses (P1. viii.) it is seen that at the I9th course is a sudden increase of thickness, none being so large for 11 courses before it and 14 after it. And this specially enlarged course is of exactly the required height of the doorway, its measures running thus :--

By levelling at entrance 37.67 by measuring courses 37.8 ; by N.E. 38.1, S.E. 37.6, NW. 37.5, SW. 39'.1	mean 37.94 ± .17	doorway height 37.95 or 37.78

Here the agreement is so exact that it is far within the small uncertainties of the two dimensions. Hence, if the passage emerged at the 19th course it would exactly occupy its height (see P1. xi.). * Besides this, it will be observed that there are two unusually small courses next over this, being the smallest that occur till reaching the 77th course. The explanation of these is clear, if the doorway came out in the 19th course ; an unusually thick lintel course was needed, so two thinner courses were put in, that they might be united for obtaining extra thickness, as is done over the King's Chamber doorway. These two courses are also occasionally united in the core masonry.

The crucial test then is, supposing the passage prolonged outwards till it intersects this course, how will its end, and the face of the casing, stand to the casing stones at the foot of the Pyramid? The answer has been already given in the list of determinations of the casing angle. It requires an angle of slope of 51° 53' 20" ± 1'; and this is so close to the angle shown by other remains that it conclusively clenches the result to which we are led by the exact equality of the abnormal course height with the doorway height.

The data for calculating the result are (1) levels of the 19th course by entrance 668.30 and 705.97; (2) floor of passage at station mark, level 611.2 (3) which is inside the edge of the base of the casing horizontally, 638.4; (4) entrance passage angle at mouth 26° 29' ± 1' ; (5) entrance passage height 47.26.

33. By a similar method the air channels give a determination of the angle of the faces. It is true that the channels did not occupy a whole course like the entrance; but as they are uniformly cut out as an inverted trough in the under side of a block' which is laid on a broad bed, it is almost certain that they similarly continued to the outside, through the one---or perhaps two---stones now stripped off; and also that their floors thus started at a course level (see P1. xi.). **

* It should be explained that this is called the 20th course by Prof. Smyth, owing to his error about the 1st course and pavement level. His measure of it is 38 inches, and the two French measures give it as 37 and 38 inches.

** In the section of the S. air channel mouth published by Prof. Smyth, certainly "the joints are not put in from any measure," nor is any other feature of it. The passage, its bed, and top, are all about half of their true size, and the form of it is unlike anything that has been there, at least since Vyse's time.

If this, then, were the case (as the N. channel cannot by its position have come out in any but the 103rd course on the face, and the S. channel in any but the 104th), they would show that the casing rose on the N. face at 51° 51' 30", and on the S. face at 51° 57' 30", as before stated. The various data are entered on the diagram of the channel mouths. The levels were fixed by measuring several courses above and below the present mouths, and thus connecting them to the course levelling at the corners of the Pyramid. With regard to the main part of these air channels, the details are given further on in the measures of the King's Chamber (section 56); and it is disappointing that they vary so much in azimuth and altitude, that they are useless for connecting the measures of the inside and outside of the Pyramid.

34. The sloping blocks over the entrance to the Pyramid, and the space below them, were examined (partly by means of a ladder), and measured ; but the details are not worth producing here, as the work of them is so rough. The large blocks are as follows, in general size :--

	E. upper.	W. upper.	E. lower.	W. lower
Length on top	(185)	(194)	151 + ×	167.7
Length below	117½	121	84 + ×	107.6
Breadth	80.0 to 91½	88.3	82.6	81.6
Height of mid-line	(114)		91	
Lean of face	20' to 2° in	2° 20' in	20' to 30' out	25' to 30' out
Angle on top	35° 40' to 39° 50' in	mean 40°	38° 45' to 50'	39° 30'
Angle on base	38° 45' to 50' in	39° 30'	39° 20' to 50'	39° 30' to 55'
Angle on butment	49° 50' to 50° 10' in	50° 40'	hidden	50° 30'

The measures in brackets are deduced from the angles and other measures. These blocks are much like a slice of the side of a casing stone in their angle; but their breadth and length are about half as large again as any of the casing stones. Their mean angle from 12 measures is 50° 28' ± 5'. The thickness of these blocks is only 33 inches, and there are no others exactly behind them, as I could see the horizontal joints of the stones running on behind them for some inches. On the faces of these blocks are many traces of the mortaring which joined to the sloping blocks next in front of them. These were placed some 70 inches lower at the top, and were not so deep vertically. By the fragment left on the E. side, the faces of these blocks were vertical. In front of these came the third pair, similar, but leaning some 7½º or 8º inwards on the face, judging by a remaining fragment. Probably a fourth and fifth pair were also placed here (see P1. ix.); and the abutment of the fifth pair shows an angle of 70½º or 73º in place of 50º. The successive lowering of the tops, leaning the faces in, and flattening the angle of slope of the stones as they approach the outside, being apparently to prevent their coming too close to the casing. These sloping blocks were probably not all stripped away, as at present, until recently, as there is a graffito, dated 1476 (half destroyed by the mock-antique Prussian inscription) on the face of the remaining block where it is now inaccessible, but just above where the next pair of blocks were placed. The sloping blocks are of remarkably soft fine-grained limestone, about the best that I have seen, much like that of the roofing of the chamber in Pepi's Pyramid; and it is peculiar for weathering very quickly to the brown tint, proper to the fine Mokattam limestone, darkening completely in about twenty years, to judge by the modern-dated graffiti.

35. Having, then, fixed the original position of the doorway of the Pyramid, we may state that it was at 668.2 ± .1 above the pavement of the Pyramid; 524.1 ± .3 horizontally inside (or S. of) the N. edge of the Pyramid casing; and its middle 287.0 ± .8 E. of the centre * of the Pyramid ; or 3723.6 from E. side, and 4297.6 from W. side, at its level; the probable error being that of fixing the length of the sides.

* Whenever any point is described as E. of the centre 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 centre of the Pyramid. Similarly of similar descriptions N., S., and W.

Thus we have the following positions in the entrance passage, reducing all to the true beginning of the floor.

		W. Floor	W. Wall Base	W. Wall Top	W. Roof	E. Roof	E. Wall Top
Doorway, original		0 ± .3	0 ± .3				
End of "basement sheet"		124.2					
Station mark		127.90					
Prof. Smyth's joint numbers	1	178.75					
	2	226.46					
	1		276.63				
	3	285.29					
	2		331.79				
	4	340.56					
	2			348.10			
	5	406.04					
	3		414.21				
	6	465.46					
	4		474.02				
Scored line			481.59				
	5		516.26				
	7	531.67					
	6		551.66				
	8	584.15					
	7		606.87				
	8		651.91				
	9		686.98				
	10	700.28					
	11	736.28					
	10		763.70				
	12	776.39					
	11		806.14				
	13	827.16					
	12		865.32				
	14	878.58					
	13		891.79				

		W. Floor	W. Wall Base	W. Wall Top	W. Roof	E. Roof	E. Wall Top
	15	915.09					
	14		926.69				
	16	963.61					
	15		967.14				
	16		996.27				
	17	1003.69					
	18	1028.59					
	17		1056.78				
	19	1063.82					
	18		1106.13				
floor ascending passage		1110.64					
	20	1127.71					
	19		1136.06				
	21	1174.22					1163.6
	20		1177.14	1177.7			
					1188.1		
						1192.4.1	
							1207.1
				1232.1			
						1243.7	
							1262.3
						1296.1	
				1318.5			
				Rock	1340.1		
					Rock		1347.5
						1350.7	Rock.
						Rock	

The above measures were taken by rods from 124.2 to 285.29 (the rods jointing together with butt ends), by steel tape from 276.63 to 1177.14, and by rods from 1163.6 to the rock; all duly corrected for temperature. On comparing them with Professor Smyth's measures, it will be found that his measures make the passage length about an inch shorter on an average; this is fairly accounted for (1) by his being all piece-meal measures added together, (2) by the rude method of making scratches with a **screw-driver** to mark the lengths of rod on the stone (L. and W. ii., 46), and (3) by there being "always a certain amount of risk as to the measuring rod slipping on the inclined floor" (L and W. ii., 35). All these errors would make the reading of the length shorter than it should be; and all were avoided by the use of a steel tape lying on the side of the floor. Nevertheless, I tested again, by rod measure, some of the points where the difference of Professor Smyth's measures were greatest from the steel tape, and they come out thus :--

Between joints	**By steel tape**	**Again by rods**	**By Prof Smyth**
5 to 6 on floor	59.42	59.45	59.2
7 on wall to 8 on floor	22.72	22.72	22.2
14 on wall to 15 on floor	11.60	11.58	10.9
14 on wall to 16 on floor	36.92	36.93	37.6
15 on wall to 16 on floor	3.53	3.47	2.9

These will practically show what errors may creep in, by not using a continuous measure like a steel tape. The object of measuring the joints, as well as the total length, by steel tape, is sufficiently illustrated by this comparison.

One source of error may arise from following the coursely-scratched prolongations of the anciently drawn lines, and of the ascending passage floor and roof. These have been made by modern measurers; and they were always rejected, and a more accurate method employed.

The measures from the steel tape onwards, by rods, down to the end of the built passage, where it rests on the rock, are not of the same accuracy as the others; the broken parts of th passage sides, and the awkwardness of measuring over the large block of granite, without any flat surface even to hold the rods against, prevented my taking more care over a point where accuracy is probably not of importance.

For the total length of the entrance passage, down to the subterranean rock.cut part, only a rough measurement by the 140-inch poles was made, owing to the encumbered condition of it. The poles were laid on the rubbish over the floor, and where any great difference of position was required, the ends were plumbed one over the other, and the result is probably only true within two or three inches. The points noted down the course of the passage, reckoning from the original entrance (i.e., the beginning of the rock on the E. side of the roof being 1350.7), are the following:--

	E.		W.
Beginning of inserted stones, filling a fissure.	1,569		1,555
Joint in these stones.	1,595		None
End of these inserted stones.	1,629		1,595
Sides of passage much scaled, 1 or 2 " off, beyond here		2,750	
Fissure in rock	3,086 - 3,116		3,066 - 3096
Mouth of passage to Gallery			3,825 - 3,856
End of sloping roof (4,137 Vyse, corrected for casing).	4,143		

36. The azimuth and straightness of the passage were carefully measured. The azimuth down the built part was taken by reference to the triangulation, which in its turn was fixed by six observations of Polaris at elongation, from a favourable station (G). The azimuth to the bottom of the rock-cut passage was observed independently, by five observations of Polaris at elongation. The observations of the straightness throughout gives a check by combining these two methods, and they are thus found to agree within 19", or just the sum of their probable errors, equal to only .09 inch lineally on the azimuth of the built part.

The results are :--

	Azimuth	Altitude
Mean axis of whole length.	– 3' 44" ± 10"	**26º 31' 23" ± 5" ?**
Mean axis of built part alone.	– 5' 49" ± 7"	
Same by offsets from 3' 44" axis.	– 5' 28" ± 12"	26º 26' 42" ± 20"?
(Same by Prof. Smyth, two days.	– 4' 27" and – 5' 34"	26º 26' 43" ± 60")

The observations of the straightness of the walls, floor, and roof of the passage, when all reduced to offsets from its mean axis of the whole length stand thus :--

Distance from original entrance	From – 3' 44" azim. W.	Mid.	E.	From 26º 31' 23" alt Roof.	Mid.	Floor.
460	21.1	.3 W.	20.5	23.2	– .4	– 24.1
710	20.9	.2 W.	20.6	23.4	– .2	– 23.9
990	20.7	0	20.8	24.1	+ .4	– 23.3
1110						– 23.4
1291	21.1?	.1 E.	21.3			
1505	20.5	.2 E.	21.0	23.8		
1741	20.4	.4 E.	21.1	23.6	– .1	– 23.9
2069	20.8	.2 E.	21.1	23.4	– .4	– 24.2
2481	21.6	.3 W.	20.9	23.4		
2971	21.0	0	21.0			
3711	21.3	.4 W.	20.5	24.3	0	– 24.3
4113?	21.3	.4 W.	20.5	23.6	– .6?	– 24.9?
4140	...	...	20.8	23.9		
Mean error		.23			.30	

(Floor at 1110 interpolated from clinometer curve.)

But the passage in the built part, and indeed for some 40 feet below that, is far straighter in azimuth than the lower part; taking this upper 2/5ths of it alone, it has a mean axis of -- 5' 49" ± 7" In azimuth, and varies thus :--

		W.	Mid.	E.
At	460	20.86	.06	20.77
	710	20.78	0	20.77
	990	20.70	.05 E.	20.80
	1291	21.23	0	21.22
	1505	20.75	0	20.75
	1741	20.76	.01 W.	20.74
Mean error			.02	

These offsets only being read to 1/20th inch (the 1/100ths merely resulting from computation) it is remarkable that the errors of the mid-line of the passage are so minute; and it shows that in this particular we have not yet gone within the builder's accuracy; readings to 1/100th inch or to I" on the longer distances, are now required.

The absolute position, then, of the middle of the S. end of the entrance passage floor will be, in level, 668.2 -- (4140 X sin. 26º 31' 23") -- .8 difference of floor offsets = -- 1181 ± 1 ?; in distance from N. base of pyramid 524.I + 3704.3 = 4228 ± 2? or 306 N. from mid-plane; and in distance E. from the mid-plane 287.0 -- [sin. (3' 55" -- 3' 44") x 3704] -- .4 difference of offsets = 286.4 ± 1.0.

37. The Subterranean chambers and passages are all cut roughly in the rock. The entrance passage has a flat end, square with its axis (within at least 1º), and out of this end a smaller horizontal passage proceeds, leaving a margin of the flat end along the top and two sides. This margin is 4.5 wide at E., 3.2 at W., and 5.4 to 6.0 from E. to W. along the top.

The dimensions and distances are as follow, from the S. end of the floor of the entrance passage (as deduced from the roof, which is better preserved) ; and the axial positions and levels are by theodolite observations :--

	Distance from End of E.P. Floor.	Distance from Mid. Plane of Pyramid.	Width E. to W. Top. Base.	Mid. from Entrance Axis, continued.	Mid. E. from Mid line of Pyramid.	..Height.. E. W.	Level above End of E. P. floor.	Level below Pyramid Pavement.
Beginning of Horiz Passage	0	306N.	40.8	.4W.	286.4	48.5	0	- 1181 floor
	20		32.9	1.0W.	285.8		Top + 38.3	- 1143 roof
Fissure	76W. 91E.							
In Passage	121		32.3 32.4					
N Door of S Chamber	218	88N.	31.6 32.7					
S Door of S Chamber	291	15N.	31.9 33.0					
N Door of L Chamber	346 *	40S.	32.0 33.3	.5W.	286.3	35.5 36.0	Top + 38.9	- 1142 roof
S Door of L Chamber	672	366S.	29.5 29.5	1.9W.	284.9	31.0 + × **	Top - 6.6	- 1188 roof
In S Passage	760		29.6 27.3					
In S Passage	900		26.7 26.7			26.3 26.0		
In S Passage	1040		28.1 29.0			28.6 27.0		
In S Passage	1180		30.1 30.0			29.5 29.3		
In S Passage End	1318	1012S.	26.0	9.7W.	277.1		Top - 2.6	- 1184 roof
Large Chamber, E. Wall 325.9; at 100 from West. Wall 329.6?; N. Wall 553.5; S. Wall 554.1							Top +125.3 #	- 1056 roof
Side Chamber	W.Wall 69½ to 70½ ; N.Wall 70.3; S.Wall 72.3						Top + 40 to + 48	- 1137 roof

The large chamber walls are therefore distant from the Pyramid central axis, 302.9 E. at N. wall; 299.6 E. at S. wall; 250.6 W. at N. wall; 254.5 W. at S. wall; 40 S. and 366 S. The central axis thus not passing through the chamber, but 40 inches inside the rock of the N. side.

In the chart above :--

* E. side of door-sill is at 351, and W. side 347, the wall not being filly dressed down there.

** This doorway rounds off at the top, rising 1½ inches in the 10 inches.

The top is + 124.3 at N. doorway, 125.4 to 127.6 at S. doorway; the roof being cut away higher, just in the corner.

The side chamber is an enlargement of the passage, westward and upward, as are all the chambers of the Pyramid; it is very rough and uneven, and encumbered now with large blocks of stone. The large chamber is most clearly unfinished, both in the dressing of the walls, and more especially in the excavation for the floor. The walls have an average irregularity estimated at ±.7 and projecting lumps of rock are left untouched in some parts. The roof is more irregular, estimated average variation ±3. The floor is most irregular, at the W. end it rises at the highest to only 10 inches from the roof; and over all the western half of the chamber it is irregularly trenched with the cuttings made by workmen to dislodge blocks of the rock. It is, in fact, an interesting specimen of quarrying, but unfortunately now completely choked up, by Perring having stowed away there all the pieces of limestone taken out of his shaft in the floor. After dislodging several blocks, I crawled in over the knobs and ridges of rock, until jammed tight from chest to hack in one place; and thence I pushed about one 140-inch rod, by means of the other, so as to measure the length up to the Western end. To measure along the W. side is impossible, without clearing away a large quantity of stones; and as there is no place to stack them safely without their going down the shaft, I could only measure the width at 100 from the W. end, perhaps somewhat askew. The lower--eastern--part of the floor, 140 below the roof, which is cotnparatively flat, is, nevertheless, very irregular and roughly trenched, quite unfinished. The best worked floor surface is just around the square shaft, 198 below the roof, and about 40 below the main part of the floor, which is 155 below roof on a knob of rock beside the shaft. The square shaft is not parallel to the chamber, but is placed nearly diagonally.*

* Like the shaft of the tomb chamber of Ti at Sakkara; an unusual plan.

Its distances to the walls are, N.W. corner 135 to N. wall ; N.E. corner 6o to E. wall ; S.E. corner 90 to S. wall. Its sides are, N.E. 68 to 75? S.E. 82½ ; S.W. 80; N.W. 70 above, 79 below (the N. corner being rounded above); N. to S. diagonal 100. The S.E. and S.W. sides stop at 67 deep, or 265 below roof, or 1,321 under pavement ; leaving a ledge about 20 inches wide, a second or deeper part of the shaft goes downwards, the N.E. and N.W. sides being continuous with those of the upper part ; it is, in fact, a smaller shaft descending out of the N. corner of the larger. The sides of the smaller shaft are, N.E. 57? S.E. 53? S.W. 60, N.W. 56. The original depth of the smaller shaft I could not see, it was apparently about 40 inches according to Vyse, when Perring sunk his round shaft down in the bottom of the ancient square shaft. This hole in the dimly-lighted chamber, about 30 feet deep (with water in it after heavy rains have rushed down the entrance passage), and with a very irregular and wide opening, makes measurement about here somewhat unpleasant. I avoided filling the shaft with the earth removed from the passage, or with the stones which Perring excavated from it, in case anyone should afterwards wish to excavate farther at the bottom. The southern passage is very rough, apparently merely a first drift-way, only just large enough to work in, intended to be afterwards enlarged, and smoothed; its sides wind 6 or 8 inches in and out.

38. The Ascending passage from the entrance passage is somewhat troublesome to measure, owing to the large plugs of granite that fill some 15 feet of its lower part; and also to the irregular way in which much of its floor is broken up.

For connecting it with the entrance passage, we must first settle the most probable value of its angle, in order to carry on the projection of its floor; and to complete it over the plugging and breakage, which prevent direct measure- ment. The angle of the whole passage will be discussed further on ; it will suffice to say here that the mean angle is 26° 2' 30"; and there is therefore a presumption that the plugged part is about the same angle, and not the 26½ ° of the entrance passage. This is confirmed by direct plumb-line measure of the angle of the plug-blocks at their lower end, giving 26° 7' (± 2'?); and noting that the end is square with the portion of passage beyond it to within 5'. Also the actual angle of the plug-blocks may be computed from Prof. Smyth's sloping measures, combined with my levelling between the floors of the passages, and plumbing up to the lower end of the plugs.*

* The elements in question are (1) Prof Smyth's plumb-line 48.5 on slope below his zero in Ascending passage ; and (2) 180.5 on slope of entrance passage, below beginning of Ascending roof. (3) My level in A. P., 71.3 on slope above C.P.S.'s zero in A.P. (4) My level in E.P. 1015.0 on slope below C.P.S.'s E.P. zero. (5) Difference of my A.P. and E.P. level marks 156.2 vertically. (6) My plumb-line on E.P. floor 1027.3 on slope below C.P.S.'s E.P. zero. (7) Height on my plumb to floor of A.P. 37.0. (8) height of plug-blocks 47.3, and angle of end 26° 7', (9) Angle of E.P. at junction 26° 21'. From these measures we get $125.1 \tan\theta + 142.9 \sin\theta = 124.7$; $\therefore \theta = 26° 12½'$

This gives 26° 12½' for the angle of the lower 300 inches of the passage; and 5' of variation would require a difference of .4 inch vertical on .9 sloping. Hence the other data confirm this so far, that it had better be adopted as the angle through the plugged part; until some one shall improve on Prof. Smyth's sloping measure, or on my levelling.

The junction of the passages was not projected over the broken part un- certainly, as had been done before; but a plumb-line was hung from the W. side of the Ascending passage roof, in front of the plug-blocks; and measures vertical, perpendicular, and sloping, were taken to the plugs, the fragments of the ascending, and the top and bottom of the entrance passage. Thus the whole was knit together to a true vertical line, the place of which was fixed on the entrance floor. From the mean of these measures, and 26° 12½ ' as the ascending angle, with 26° 21' as the descending angle at that spot (by Prof Smyth), the Ascending passage roof starts vertically over 1110.90 on the sloping floor of the entrance, reckoning from the casing face; and the floor cuts the entrance floor at 1110.64 from the same, both probably ±.1.

Further, the lower end of the plug-block is 74.19 from the intersection of the floors; and the upper end 50.76 from the intersection of the roofs. Having thus fixed the beginning of the Ascending passage, by the point where its floor produced onwards intersects the floor of the entrance passage, we can proceed up the Ascending passage from this as a starting point. The distance past the plug-blocks being determined as above described, and that from the plug-blocks to the S. end of the passage, by steel tape measure on the E. side of the floor; then, the tape being corrected for temperature and tension, the results are thus, on the sloping floor :--

		Floor, E. side.	Base of E. wall.
Junction of passage floors		0	0
Beginning of actual floor		59.8	
Base of plug-blocks		74.2	
Top of plug-blocks, present		252.7	
Top of plug-blocks, ancient		277?	
Joint numbers.			
Smyth's.	Dixon's.		
1	27	298.2	298.2
(Petrie's levelling mark		324.0	
2	26	about 333.6	333.6
	25		374.9
6	23	496.6	496.6
7	22	552.3	552.3
	21		593.3
8		604.4	
	20		637.9
	19		690.3
10	18	716.3	716.1
11	17	749.0	748.9
12		799.1	
	16		812.1
	14		848.1
13		854.2	
15	13	922.4	922.2
16	12	955.0	955.3
	11		1006.9
17		1008.0	
	10		1044.9
19		1080.3	
	9		1095.0
20	8	1130.0	1129.9
21	7	1161.5	1161.5
22		1202.4	
	6		1214.2
23		1255.4	
	5		1273.2
25	4	1337.9	1337.9
26		1368.6	
	3		1377.7
27		1427.1	
28		1488.7	
	2		1515.5
Gallery, plumb from wall over door		1546.5	
29 Floor joint		1546.8	
Wall joint and edge over door	1		1547.0

On comparing these measures with Prof. Smyth's, it will be seen that he makes the passage about 3 inches shorter; and that this difference mainly occurs in the lower part, where the floor is much broken. Several lengths were therefore measured as tests, just as in the entrance passage, and the results are :--

	1st measure by tape.		2nd measure by tape.		Prof. Smyth, by one rod.
Mark (1) to mark (2)	50.0		50.1		
Mark (1) to 22 (Dixon)	56.3		56.3		
22 Dixon to 21 Dixon	40.9	52.1	41.0	52.1	49.7
21 Dixon to 8 Smyth	11.2		11.1		
8 Smyth to 20 Dixon	33.3		33.5		
20 Dixon to mark (3)	8.3		8.2		
			by rods		
11 Smyth to 12 Smyth	50.1		50.2		50.2
12 Smyth to 16 Dixon	13.0	55.1	13.3	55.1	55.3
16 Dixon to 14 Dixon	36.1		36.1		
14 Dixon to 13 Smyth	6.1		5.7		
13 Smyth to 15 Smyth	68.2		68.4		67.7

The close agreement of these two series of measures, particularly in those parts twice measured by tape, will show (as in the entrance passage) that the error is certainly in the rod measures, and due to the same causes as the error in the entrance passage, i.e., slipping, irregular placing on broken floor, and the marking off of each length.

The result therefore is that from the intersections of entrance and ascending passage floors, to the floor joint at the E. side of the grand gallery doorway, is 1546.8 on the slope.*

* On the W. side this joint is 1.2 N. of the side joint of doorway.

The granite plugs are kept back from slipping down by the narrowing of the lower end of the passage, to which contraction they fit. Thus at the lower, or N. end, the plug is but 38.2 wide in place of 41.6 at the upper end: the height, however, is unaltered, being at lower end 47.30 E., 47.15 mid, 47.26 W.; and at upper, or S. end 47.3. In the trial passages the breadth is contracted from 41.6 to 38.0 and 37.5 like this, but the height is also contracted there from 47.3 to 42.3. These plug-blocks are cut out of boulder stones of red granite, and have not the faces cut sufficiently to remove the rounded outer surfaces at the corners: also the faces next each other are never very flat, being wavy about ±.3. These particulars I was able to see, by putting my head in between the rounded edges of the 2nd and 3rd blocks from the top, which are not in contact; the 2nd having jammed tight 4 inches above the 3rd. The present top one is not the original end; it is roughly broken, and there is a bit of granite still cemented to the floor some way farther South of it. From appearances there I estimated that originally the plug was 24 inches beyond its present end.

It has been a favourite idea with some, that two horizontal joints in the passage roof just south of the plugs, were the beginning of a concealed passage: I therefore carefully examined them. They are 60.5 (or 60.1 second measure) apart vertically, and therefore quite different to the passages of the Pyramid, which are 47 perpendicularly or 52 vertically. Further, there is no possibility of the blocking up of a passage existing there; as the stone of the roof is continuous, all in one with the sides ; the three roof-blocks between the two horizontal joints are all girdle-blocks, either wholly round the passage, or partially so; and the block N. of these is a long one, over 125 inches from E. to W., and continuous into both walls. These vertical girdle-blocks are a most curious feature of this passage (first observed and measured by Mr. Waynman Dixon, C.E.), and occur at intervals of io cubits (206.3 to 208.9 inches) in the passage measuring along the slope. All the stones that can be examined round the plugs are partial girdle-blocks, evidently to prevent the plugs forcing the masonry apart, by being wedged into the contracted passage. Many of the stones about the blocks in Mamun's Hole are over 10 or 11 feet long; the ends are invisible, but probably they are about 15 feet over all.

39. For the angle of the passage, and its straightness, it will be well to consider it all in one with the gallery floor, as they were gauged together all in one length. The angle of slope I did not observe, as I considered that that had been settled by Prof Smyth; but the azimuth was observed, by a chain of three theodolites, round from the entrance passage. The straightness was observed by offsets to floor and side all along it, read from a telescope at the upper end of the plug-blocks. When I came to plot the results, I found that there were no measures taken at the point where Prof. Smyth's theodolite was set up. The sloping floor is nowhere, having been entirely cut away at the beginning of the gallery; and the top of the ramp (to which the theodolite had been referred) was not offsetted by me, nor was its slope measured by Prof Smyth's clinometer for 300 inches from the place. Hence we cannot say exactly what direct relation the theodolite bore to the passage; but we can obtain the angle of slope very satisfactorily, by taking the angles observed to signal at bottom of ascending passage, and to signal at top of gallery, and then (knowing the distauces of these signals) calculate the angle of slope from signal to signal. This, when corrected for lower signal being 3 too high, gives **26º 12' 50"** for mean angle of both passage and gallery together. Hence, from my offsets to the places of these signals, the absolute angle, and the variations from it, can be obtained for either part independently. Thus we have the form and direction of the ascending passage, reckoning from the beginning of its floor on the entrance passage floor, with its variations, as follows :--

From beginning	From – 4' ± 3' azimuth			From 26º 2' 30" altitude		
	W.	mid.	E.	roof.	mid.	E. floor.
69				23.1	– .5	24.1
260	20.8	0	20.7	23.6	0	23.6
520			21.6			23.5
650			20.9			22.4
700			20.7			
840			21.4			23.3
1045			21.3			23.7
1220			21.9			24.1
1365			21.2			23.9
1540	21.0	0	21.1	23.9	+ .1	23.6

The surfaces are so much decayed and exfoliated, that it is only just at the ends that two original faces can be found opposite to one another; hence the width and height cannot be measured, and the offsets can only be stated to one surface.

From this altitude, the sloping length of the passage being 1546.8, the horizontal length will be 1389.5, and the vertical height 679.7, both being corrected for difference in the offsets of the ends. The determination of the azimuth has, unhappily, a large probable error, ± 3' (owing to bad foundation for the theodolite in Mamun's Hole); and its direction, -- 4', is so close to that of the Pyramid side, that it may be assumed parallel to that ± 3'. This, on the passage length, = 1.2 inches for the probable error of the place of the upper end of the passage, in E. to W. direction in the Pyramid.

These, added to previous amounts, give for the absolute place of the floor end at the latitude of the E. wall of the gallery (172.9 + 679.7) = 852.6 ± .3 level above pavement; (1517.8 + I389.5) = 2907.3 ± .6 horizontally from N. edge of Pyramid, or 1626.8 ± .8 northwards from centre; and 287 ± 1.5 for middle of passage eastward from centre of Pyramid.

40. The horizontal passage leading to the Queen's Chamber is the next part to be considered. This was measured with steel tape all along, and the levels of it taken with theodolite. The results for its length and levels are thus, reckoning from the mean door of the gallery at 1546.8 from beginning of ascending passage :--

	Distance from Doorway	Northward from Pyramid centre	Floor level	∴ Roof level
Mean doorway on floor	0	1626.8 ± .8	852.6 ± .3	
On flat floor	52	1575 ± .8	858.4 ± .3	
Floor joint, No. 8, Smyth	312.0	1314.8 ± .8	857.4 ± .3	903.8
Floor joint, No. 16,	623.0	1003.8 ± .8	856.1 ± .3	902.3
Floor joint, No. 21,	870.2	756.6 ± .8		
On floor	1000	627 ± .8	856.2 ± .3	902.4
Floor joint, No.25, Smyth	1177.7	449.1 ± .8		
Step in floor	1307.0	319.8 ± .8	854.6 ± .3	901.0
			834.9 ± .3	
Chamber N. wall, top of door	1523.9	102.9 ± .8		
Chamber N. wall, side of door	1524.8	102.0 ± .8		
Floor joint, No.30, Smyth	1527.0	99.8 ± .8		
Niche, N. side	1620.7	6.1 ± .8	834.4 ± .3	
Niche, first lapping				901.3
Chamber, E. apex	1626.5	.3 ± .8		1080.1

The azimuth of this passage was not measured, but the beginning of it is 287 ± 1.5 E. of the middle of the Pyramid ; then for the axis of it at the end we may say the same, or 287 ± 3, since the gallery above it only differs about two inches from that quantity. In the above measures of length there is a steadily accumulating difference of about 1 in 300 between Prof. Smyth's measures and these, for which it seems difficult to account; but as in the other passages, I have always found on retesting the measures, that such differences are due to errors in the cumulative single rod measures, and not in my steel tape (which was always verified at the starting point after measuring), it seems unlikely that the steel tape should be in error here. Hence I should adopt these measures without alteration.

41. In the Queen's Chamber it seems, from the foregoing statement, that the ridge of the roof is exactly in tbe mid-place of the Pyramid, equidistant from N. and S. sides; it only varies from this plane by a less amount than the probable error of the determination. x

The size of the chamber (after allowing suitably in each part for the incrus-tation of salt) is on an average 205.85 wide, and 226.47 long, 184.47 high on N. and S. walls, and 245.1 high to the top of the roof ridge on E. and W. walls. The variations of the horizontal quantities in detail are as follows, from the mean dimensions.

Above Floor	From below Apex, E. Wall.			From below Apex, W. Wall.			Below Ridge of Roof.		
	To N. Wall.	(sum)	To S. Wall.	To S. Wall.	(sum)	To N. Wall.	W.Wall.	to	E.Wall.
Mean of All	102.92	205.68	102.76	102.67	206.02	103.35		226.47	
240							– .46	225.51	– .50
210							– .31	225.79	– .37
180	+ .16	205.67	– .17	– .14	broken		– .24	226.12	– .11
156	+ .06	205.60	– .14						
127	+ .10	205.72	– .06	– .16	206.15	+ .29	0	226.37	– .10
99	+ .02	205.79	+ .09						
76				– .09	205.68	– .25	+ .24		
67	– .32	205.63	+ .27				+ .27	226.91	+ .17
8				+ .37	206.29	– .06			
0							+ .45	227.47	+ .55

For example, to take the first entries, at 180 inches over the floor, on the E. wall, the N. wall is (102.92 + .16) = 103.08 from a vertical line below the apex of the roof; and the S. wall is (102.76 --.17) = 102.59 from the same apex line : the sum of these quantities, or the total width, being 205.67. Thus the mean distances of the N. and S. walls from the apex on the E. and W. walls is given at the top of each column ; and beneath that the small variations from those mean vertical wall faces. In the last division are given the distances of the E. and W. walls apart, below their apices ; both the mean dimension, the variations from it, and the total at each point. It will be observed that the E. and W. walls have both a uniform tilt inwards; if we allow 14' for this as an average, the mean from a straight line inclined that amount is .057 on E. and .025 on W. ; a remarkably small amount of error, comparable to the extremely fine work and close joints of the stones themselves. Also the ridge of the roof is not exactly over the middle of the chamber at either end. Beside the above resulting length of the middle of the chamber on the floor, separate measures were taken on the two walls; these give N. 227.41, middle (from above) 227.47, S. 227.61 ; mean of all 227.50 for floor length.

42. In the matter of height, the courses vary a good deal ; and far more care was spent on the closeness, than on the regularity of the joints. For a starting point in measurement, the general floor is hopelessly irregular, consisting plainly of rough core masonry; and furthermore, it has been built over with similar rough masonry, which was afterwards stripped down to insert the chamber walls. This is proved by there being no fewer than eight edges of sunken spaces upon it, made (according to the universal habit of pyramid builders) to let in the inequalities of the upper course into the surface of the course below it. These sunken edges are well seen in other parts of the core masonry, and their meaning here is unequivocal. But all round the chamber, and the lower part of the passage leading to it, is a footing of fine stone, at the rough floor level; this projects I to 4 inches from the base of the walls, apparently as if intended as a support for flooring blocks, which have never been introduced. It is to this footing or ledge that we must refer as the starting point; though what floor was ever intended to have been inserted (like the floor of the King's Chamber, which is inserted between its walls) we cannot now say. Certainly, a floor at the level of the higher part of the passage, would not reconcile everything ; as that higher floor is also not a finished surface, but has sundry large round holes in it, like those in the chamber floor and elsewhere; intended, apparently, for use in process of building. Starting, however, from this footing at the base of the walls, the mean elevation of each course above the floor is as follows, with the variation + or - from the mean scale, at eleven points around the chamber :--

Mean of Corners	N.W. Corner			N.E. Corner			E. Side	Niche	S.E. Corner			S.W. Corner			W. Side
	W.		N.	N.		E.	Mid		E.		S.	S		W.	Mid
							N.+1.0								S. -.5
245.1							S. -.1								N. -.6
214.35							+ 2.05								- 2.05
184.47		- .37			- .18		- .47	- .47		- .01			+ .55		- .67
179.09	+ .67					- .73			- .39					+ .45	
156.07	+ .23		- .05	+ .67		- .09	+ .33	+ .29	+ .01		- .35	- .49		- .01	- .17
127.13	- .23		- .11	- .03		+ .12	+ .17	+ .28	+ .50		+ .31	- .41		- .20	- .33
99.13	+ .01		- .17	- .13		+ .05	- .03	+ .05	+ .32		- .11	- .09		+ .08	- .13
67.44	+ .28		+ .06	- .23		0	+ .09	- .12	+ .06		- .22	- .05		+ .09	- .05
34.13	+ .01		- .24	door		0	+ .17	- .01	+ .22		+ .02	+ 3.08		+ 3.38	- .19
0		- .18			+ .20		- .2	+ .42							- .26

The mean course thicknesses, and their mean differences being-from the base upwards-thus : - 34.13 m.d. '19, 33.31 m.d. .18, 31.69 m.d. .14, 28.00 m.d. .21, 28.94 m.d. .27, 28.40 m.d. .48 to top of N. and S. walls. In the first column above, 245'1 is the apex of the E. and W. walls, where the sloping roof stones end at their junction; and the differences entered here, N. and S., are due to the N. and S. slabs not ending at the same level, one having fallen a little below the other in building; the highest shows, therefore, probably the intended point, and this is 1080.1 above the pavement. 214.35, in the first column, refers to the topmost joint on the E. and W. walls. 184.47 is the top of the N. and S. walls, and a joint on the E. and W. walls. 179.09 is a joint that occurs at each side of the E. and W. walls, but which does not run far, being soon shifted upward to the 184 level. 156.07, 127.13, 99.13, are all joint levels around the chamber. 67.44 is a joint level, signalized by the top of the doorway and of the channel mouths in N. and S. walls. 34.13 is a course around the chamber. And 0 is the fine stone footing of the walls, which is about the level of the variable and rough floor of the chamber. It must be remcmbered that the above figures only give differences from a mean scale, and do not profess to be levels; the columns, in fact, being only rigidly connected at the two sides of any one corner, which hence have no dividing line between them in the table. Assuming, however, that the above series of heights of E. and W. walls are pretty closely adjusted to the heights in the corners next to each, we have for the sloping roof block, the following figures, calculating from the above quantities :--

	E. end, N. side.	W. end, N. side.	E. end, S. side.	W. end, S. side.
Sloping length	120.00	119.96	119.12	118.59
Angle	30º 48'	30º 14'	30º 33'	30º 10'

These roof blocks are seen-where Howard Vyse excavated beneath one at the N.W. corner-to go back 121.6 on slope, behind the wall face; this, coupled with the thickness of these blocks (which is certain, by similar examples elsewhere, to be considerable) throws the centre of gravity of each of the slabs well behind the wall face,* so that they could be placed in position without pressing one on another. Hence there is never any arch thrust so long as the blocks are intact ; they act solely as cantilevers, with the capability of yielding arched support in case they should be broken.

* As at Sakkara, in the Pyramid of Pepi.

The projection on the western side of the doorway, mentioned by Professor Smyth, is really a surplus left on both sides of the corner ; in order to protect the stone in transit and in course of building. This undressed part in the chamber, is cut away down to the true surface at the top and at the middle joint, in order to show the workman exactly to where it needed to be dressed in finishing it off; The excess in the chamber begins 1.3 below joint at top of doorway, and thence projects 1.4, with a width of 5.5; it is dressed away for 1'05 at the middle joint, and then continues sloping away rather thinner down to the floor. The projection into the passage is 1'5 maximum at base, usually .8 ; and it is 5.5 maximum width,or usually 4.5.

43. The niche in the eastern wall of this chamber, from its supposed connection with a standard of measure, was very closely examined. Its original depth back was certainly only 41 inches at every part from the bottom upwards. The surface that might be supposed to belong to the side of a deeper part, is only that of a joint of masonry, one stone of which has been broken up and removed; this is evident as there is mortar sticking to it, and as it is pick-dressed, quite different to the fine surfaces of the niche sides ; beside this, it is not flush with the side, or any of the overlappings of the niche; and moreover, all down the niche sides are the traces of the edge of the back, at 41 from the front, where it has been broken away.

The general form of the niche was a recess 41 inches (2 cubits) deep back 62 inches (3 cubits) wide at base, and diminishing its width by four successive overlappings of the sides (at each wall course), each of ¼ cubit wide, until at 156 high it was only 20 (1cubit) wide, and was finally roofed across at 184 high. Thus, of the 3 cubits width of the base, one cubit was absorbed on each side by the overlappings, leaving one cubit width at the top. This cubit is the regular cubit of 20.6 inches, and there is no evidence of a cubit of 25 inches here. The exact dimensions of every part are as follow, giving the mean dimensions, and the variations of each part, + or --, from the mean. All corrected for the salt exudation on the two lower laps, as estimated at each point; there is no salt on the upper three laps :--

44. The channels leading from this chamber were measured by the goniometer already described (A, section 10); they are exactly like the air channels in the King's Chamber in their appearance, but were covered over the mouth by a plate of stone, left not cut through in the chamber wall; no outer end has yet been found for either of them, though searched for by Mr. Waynman Dixon, C.E., who first discovered them, and also by myself on the N. face of the Pyramid.

The N. channel is 8.6 high, and about 8 wide in the chamber wall, running horizontally for 76 inches, and then turning upwards. The S. channel is 8.8 high, and runs 80.0 to its turn upwards. The mean angles, measured between the horizontal part and the ascending slope of the channels, are thus :--

N. Channel				S. Channel			
W.	Mid.	E.	Mean	W.	Mid.	E.	Mean
37° 33'	37° 25'	37° 25'	37° 28'	38° 28'	38° 20'	38° 35'	38° 28'

each statement being the mean of two observations, which never differed more than 6'. Hence, if these channels were continued to the outside of the Pyramid, their floors would end on the Pyramid faces at 2641.3 above the base, and 2460.8 from the centre of the Pyramid on the N. face; and at 2679.1 above the base, and 2431.2 from the centre on the S. face. I observed something like the mouth of a hole in the 85th course on the S. face, scanning it with a telescope from below; but I was hindered from examining it closely.

Interior passageways and chambers ... sectional views

45. Returning now to the gallery from which we diverged to the Queen's Chamber, the length of the gallery was measured like the other passages, with the steel tape, but not many joints were measured, and those were on the E. ramp, on which the tape was laid at 6 inches from the edge. The offsets to the floor and E. ramp were also read, in continuation of the series of the ascending passage, as explained before (section 39). The results are as follow, starting from the N. wall of the gallery, at 1546.8 from beginning of ascending passage.

	Distance on slope	Variations from mean axis of +1'20" azimuth			Variations from mean axis of **26° 16'40"** altitude	
		W.	Mid.	E.	Ramp top	Floor
N. wall	0	...	...	...	{1.6	22.3}
At	30	20.9	.1 E.	21.2	...	...
First joint, vertical	44.6	...	...	...	...	...
At	150	20.7	.2 W.	20.3	...	...
Joint at "cut off" vertical	223.2	...	...	...	...	...
Face of "cut off"	223.7	...	...	...	...	...
Second "cut off"	263.8	...	...	...	...	...
Joint	264.1	20.9	0	20.9	2.0	22.9
At	400	21.0	.2 E.	21.4	2.3	23.1
At	700	20.8	.4 E.	21.6	2.6	23.6
Joint	912.4	...	...	...	...	...
At	1000	21.1	0	21.0	1.5	23.4
Joint, broken to next	1087.0	...	...	...	...	...
Joint	1186.5	...	...	...	...	...
At	1300	21.5	.3 W.	20.8	2.3	23.3
Joint	1454.6	...	...	...	...	...
At	1600	21.2	.1 E.	21.4	2.1	22.2
Ramp end	1815.5	21.3	0	21.2	1.8	22.1
S. wall, in same line	1883.6	...	...	...	...	...

In the variations in altitude, the height of the axis above the ramp top is stated, as well as its height over the floor. The axis, though different in azimuth and altitude from that of the ascending passage, is reckoned to start from the end of it; hence the offsets are a continuous series, though measured from a line which is bent on passing from the passage to the gallery. The first-stated floor offset here (in brackets) is not what the continuation of the floor of the ascending passage actually is at the point; but it is the virtual floor of the gallery, i.e., where it would come if the trend of the rest of the gallery was continued, and also (judging by the altitude observations of Prof Smyth) where it would come if continued parallel to the ramp top.

By successive rod measures, Prof. Smyth made the gallery 8 shorter than it appears by this continuous measure; but the continuous measure is certainly better in principle and also in practice, as we have seen in the other passages. The steel tape of 1200 inches required to be shifted in order to measure from one end to the other of the gallery, and three points were common to both tape lengths ; the distances between these points were 305.5 by first, 305.6 by second measure, and 480.2 by both first and second measures, showing the same accuracy in this as in the taping of the other passages. The difference between Prof. Smyth's measures and the taping occurs almost entirely from the N. wall to the cut out in the floor, and is probably due to want of straightness and squareness in one or other of those surfaces.

Hence the floor of the gallery intersects the S. wall at **1689.0 ± .5** above the pavement; at 61.7 ± .8 S. of the Pyramid centre; and its middle is 284.4 ± 2.8 E. of the Pyramid centre; reckoning the measures of length and angle continuously through from the plug-blocks upwards, so as to avoid all un-certainties of connection at the beginning of the gallery, and duly correcting for difference in offsets.

46. The holes cut in the ramps or benches, along the sides of the gallery (see section of them in P1. ix.), the blocks inserted in the wall over each, and the rough chopping out of a groove across each block-all these features are as yet inexplicable. One remarkable point is that the holes are alternately long and short, on both sides of the gallery; the mean of the long holes is 23.32, with an average variation of .73, and the mean of the short holes is 20.51, with average variation .40. Thus the horizontal length of a long hole is equal to the sloping length of a short hole, both being one cubit. This relation is true within less than half their average variations.

The roof of the gallery and its walls are not well known, owing to the difficulty of reaching them. By means of ladders, that I made jointing together, I was able to thoroughly examine both ends and parts of the sides of the gallery. The roof stones are set each at a steeper slope than the passage, in order that the lower edge of each stone should hitch like a paul into a ratchet-cut in the top of the walls; hence no stone can press on the one below it, so as to cause a cumulative pressure all down the roof; and each stone is separately upheld by the side walls across which it lies. The depth of two of these ratchet-cuts, at the S. end, I measured as 1.0 and 1.9 to 2.0; and the angles of the two slabs there 28º 0' to 28º 18', and 27º 56' to 28º 30', mean 28º 11'; which on a mean slab 52.2 from N. to S., would differ 1.74 inches from the passage slope. The edge of the southernmost slab is 14.5 from the S. wall; the next slab is 47.4 from N. to S.

The verticality of the ends of the gallery was measured from a plumb-line; and bottom of each of the laps of stone and the horizontal distances of the top from the ends of the roof are thus:--

Laps		N. End		Lean out	S. End	Lean in	High on S. End	Lap on W. side
8		0 ?			0		33.6	
7	top	3.0			2.9			2.3
7				0		– .08	33.7	
7	base	3.0			2.8			
			h					
6	top	6.2			5.8			3.1
6				+ .2		0	33.0	
6	base	6.0			5.8			
			s					
5	top	9.1			9.00			3.0
5				+ .6		0	34.0	
5	base	8.5			9.00			
			h					
4	top	11.9			12.08			2.9
4				– .2		+ .10	33.8	
4	base	12.1			12.18			
			h					
3	top	15.1			15.08			
3				+ .1		+ .10		
3	base	15.0			15.18			
			s					
2	top	19.7			18.10			
2				+ .1		+ .45		
2	base	19.5			18.55			
1	top	19.6			21.5			
1				+ .4	21.7	– .25		
1	base	19.2			21.25			
				+ 1.2		+ .32		

The letters h and s in the column of the N. end show the under edge of the lap of stone to be either horizontal or sloping; on the S. end it is always horizontal. The width of the top of the gallery is 40.9 at N., and 41.3 at S. end. The remarkable groove in the lower part of the third lap,. along the whole length of the sides, was measured thus, perpendicularly :--

	N. W.	N. E.	S. W.	S. E.	mean
Groove upwards from lap edge	11.7	11.8	11.2	11.0	11.4
					– 6.1
	to 5.4	5.7	5.1	5.1	5.3

At the S.W. it is cut to a depth of 8 inch, at the S.E. to .6 (?); the upper edge of it is often ill-defined and sloping. According to Prof. Smyth the mean height of this lap above the gallery floor is I66.2 ± .8 vertically; hence the groove is at 172.1 to 179.0 vertically over the floor, and its lower edge is there-fore at half the height of the gallery, that varying from 167 to 172. The pickmarks in the groove on the S. end of the W. side are horizontal, and not along the groove, showing that it was cut out after the walls were built, which agrees with its rough appearance. It belongs to the same curious class of rough alterations as the blocks inserted in the sides of the gallery and the rude grooves cut away across them.

At the top of the N. end is a large forced hole, cut by Vyse in 1837, and still quite fresh-looking. The whole of the top lap of stone is so entirely cut away there that I could not decide to where it had come, and only suppose it to project 3 inches, like the others.

From this the length of the roof of the gallery is 1688.9 -- 40.45 = 1648.4 horizontal, or 1838.6 sloping.

By plumb-line measure at the S. end, the roof on the E side is inside the floor edge (or overhangs) 20.50, and on the W. side 20.40. On the S. end (eliminating the lean) the projection is 20.9, and on N. 20.4; mean of all, 20.55, for the sum of the seven projections of the laps, or one cubit, the laps being then one palm each in breadth. Thus the laps overhang the ramps along the gallery sides, and the space between the ramps (2 cubits), is equal to the space between the walls at the top.

The remarkable shaft, or "well", that leads away from the lower end of the gallery down to the subterranean passage, was fully measured about its mouth but it appears to be so rough and so evidently utilitarian (for the exit of work- men) that it is not worth while to publish more complete measures than those of Prof. Smyth. As, however, the position of its mouth has been supposed to have a meaning, it should be stated that the opening is from 21.8 to 49.0 horizontally from N. wall of gallery on floor, 21.8 to 48.7 near its top, and 21.9 to 48.9 by the sloping distance reduced. Thus the middle of it is at 35.40, 35.25, or 35.37 by different methods. The part of the shaft that passes through a rock fissure filled with gravel (often called the "grotto") has been steined with 10 courses of small stones, varying from 7¼ to 8 inches in height.

At the upper end of the gallery, we have already stated the S. wall to be 61.7 ± .8 5. of the Pyramid centre; and hence the face of the great step at the head of the gallery (which descends behind both floor and ramps) is (61.7 -- 61.3) = .4 ± .8 S. of the Pyramid centre. It may, therefore, be taken as intended that the face of this step, and the transition from sloping to horizontal surfaces, signalizes the transit from the Northern to the Southern half of the Pyramid. This same mid-plane of the Pyramid being also signalized by the mid-plane of the Queen's Chamber, which is measured as .3 ± .8 N. of the Pyramid centre.

The ramps along the sides, where they join this great step, are very irregular. Their top surfaces slope away downwards toward the side walls; thus the E. ramp top varies from 13.20 to 12.18 below the step from E. to W., and the W. ramp top from 12.82 to 12.2 (?) from W. to E. At present, more-over, the ends of the ramps are parted away from the face of the step by .30 on E. and .44 on W., an amount which has been duly subtracted from my length measures of the gallery. Beside this, the top of the step itself, though, straight, is far from level, the W. side being about 1.0 higher than the E. side. And the sloping floor seems to be also out of level by an equal amount in the opposite direction ; since on the half width of the step (i.e., between the ramps) the height of the step face is 34.92 or 35.0 on E., and 35.80 or 35.85 on W. The length of the step from N. to S. is on E. side 61.0, and on W. 61.5. All these measurements are very carefully taken with elimination of wear, fractures, and shifting of the stones at the joints. Hence, at the line along which I measured, 6 inches from the edge of the ramp, the step will be 61.1 long; and this at the angle 26º 12' 50" (by which the end of the gallery was calculated from the plug-blocks) will be 30.08 vertically, for the virtual * above the actual floor end.

* The virtual floor end is where the general floor slope, if carried on through the step, would intersect the plane of the S. wall.

Then the top of the step will (by above measures) be here 34.88 above actual floor end, and the step dips about .64 to the S. wall at this part ; so the top of the step at the S. wall is 34.88 -- .64 -- 30.08 = 4.16 (say ± .2) above the virtual floor end at the line of taping. And as the virtual floor end is at 1689.0 ± .5, the step surface at the E. side of the S. doorway is 1693.2 ± .6 over the pavement.

47. The Antechamber and its passages were measured both by steel tape and rods, in one length, from the step to the King's Chamber; and the joints and floor levels are as follow :--

	Along Floor on E. side	Southwards from centre of Pyramid	Level over virtual end of Gallery ± .2	Level over pavement ± .6
Face of step	– 61.32	.4	4.7 E. 5.6 W.	1693.7 to 1694.6
S. wall of Gallery	0	61.7	4.2 E.	1693.2
N. end of Antechamber	52.02	113.7		
Joint, granite begins	64.90	126.6	3.6 and 3.9	1692.6 and 1692.9
Granite of wall begins	75.26	137.0		
Edge of wall begins	91.79	153.5		
Joint of floor	112.15	173.8	3.7 and 3.2	1692.7 and 1692.2
Edge of wall groove	113.58	175.2		
Edge of wall groove	119.26	181.0		

	Along floor on E. side	Southwards from centre of Pyramid	Level over virtual end of Gallery ± .2	Level over pavement ± .6
Joint of wall	134.17	195.9		
S. end of Antechamber	168.10	229.8		
Joint of floor	198.41	260.1	2.9 and 2.8	1691.9 and 1691.8
Base of King's ch. wall	268.9	330.6	– .5	1688.5
End of passage floor	269.04	330.7	3.0	1692.0
Raised floor, King's ch.	269.17	330.9	3.8	1692.8

These measures vary somewhat from those of Professor Smyth in 1865; and, comparing the greatest differences, they stand thus :--

	Steel tape 1882	Rods 1880	Rods 1865
N. end Antichamber to joint S. of it	12.88	12.88	13.6
Next joint to S. end of Antichamber	55.95	55.73 and 55.80	55.5

So here, as elsewhere, the measures in 1880 - 2 by steel tape and rods, entirely independent of each other, agree fairly together, and suggest that the 1865 rod measures were somewhat in error. This is due generally to the latter starting from different points on different occasions, and to their different series being insufficiently locked together. Hence I adopt the steel tape measures as the most satisfactory.

48. Taking the Antechamber alone, we may say that its dimensions above the granite wainscot of the sides, are as follow :--

	Length N. to S.				Breadth E. to W.			
Height above floor	2 from W.	Middle	12 from E.	E. side	2 from N.	40 from N.	76 from N.	2 from S.
147	116.85	116.22	116.05	115.65	64.80	64.48	64.96	64.76
129	117.00	116.18	116.03	115.37	64.72	64.98	65.26	65.25
114	117.00	116.11	115.73	114.07	65.06	65.00	65.48	65.21
95	116.55		115.91					
70	116.58		115.93					
45	115.91		116.12					

Diagonals N.W to S.E			
	133.15 at 2 from ceiling.	133.14	N.E to S.W.
	133.07 over wainscot.	132.98	

The height was measured as follows :--

	Near N. wall	14 from North	59 from North	61 from North	S. wall
At E. side	149.47	149.09	149.17	149.62	149.63
Middle	149.53			149.64	149.64
At W. side	149.32	149.01	149.10	149.65	149.57
Mean	149.44	149.05	149.13	149.64	149.61
Above gallery end	153.04	152.95	152.83	152.84	152.61

The mean length is thus 116.30 (by the two series from top to base), breadth 65.00, and height 149.35 ; or the ceiling over the virtual end of the gallery floor, 152.85 ± .2, and 1841.8 ± .6 over the pavement.

49. Coming now to details of the walls, the rough and course workmanship is astonishing, in comparison with the exquisite masonry of the casing and entrance of the Pyramid; and the main object in giving the following details is to show how badly pyramid masons could work. The great variation in the foregoing measures illustrates this. The N. wall is all rough picked work, with 2 variation commonly; there is a great irregular flaw, and a piece broken out of the stone about the level of the top of the leaf, as much as 1 inch deep. The E. wall has the granite by the side of the leaf wavy and winding, and bulbous at the base, projecting 1.4. On the wainscot block at the S. end of this wall, which is all in one with the S. end of the chamber, are two conjoined deep scores or scrapes nearly vertical, much like the beginning of a regular groove; their distance from the S. wall is 3.6 to 7.2 at 90, and 2.6 to 6.4 at 52 from floor, where they end; they are .48 deep at maximum. The S. wall has all up the E. side of it, over the wainscot, a projection, just equal in width to the wainscot, and varying in thickness from .31 at top to 1.7 half-way down, and thence fading off down to the top of the wainscot. On the W. side of the S. wall the granite has been daubed over for 2 to 6 inches in breadth, with a thin coat of cement; this, at 1 inch from the side is .35 thick ; also at 13 from the W. side is a slight sinking of the granite, from .34 to .60 in depth, all quite ill-defined. The W. wall has the top of the granite wainscot uneven, rising toward the front, and there sinking suddenly .35 at 1.4 from the front edge. The southern of the three semicircular hollows on the top of this wainscot (see P1. xii.)* has the granite defective at the back of it, and is backed with rough limestone there.

* The forms of the curves are plotted from offsets taken at every inch along them.

The southernmost stone over the wainscot is dressed very flat and true, but rough, + or -- .03. The next block has a raised edge to it on the S. side (figured by Prof. Smyth), and along the base of it, which consists of granite left rough, not dressed away in finishing; about 4 inches wide, and .4 projection along the lower edge of the block; and 2 wide and 1.2 maximum projection at the side. The other edges of this block were marked out by saw-cuts in the granite, about .2 deep, to guide the workmen in dressing the face.

The various courses and stones of the chamber were measured, but,the only points of interest are the following.

The south wall has four vertical grooves all up it, which have been hitherto supposed to have extended down to the top of the passage to the King's Chamber. This was not the case, however; for, though much broken away, it is still clear that they became shallower as they neared the bottom, and probably ended leaving an unbroken flat surface over the doorway. Their depths (as well as the forms of their sides) show this, as follows :--

Height above door	E. groove	2nd	3rd	W. groove
at 10 at 7 at 5	2.8 2.5 1.75	much broken	slight curve	2.8 at 8 2.5 at 7 2.0 at 5½

50. The granite leaf which stretches across the chamber, resting in grooves cut in the granite wainscots, must be somewhat less in width than the breadth between the grooves, i.e., 48.46 to 48.76. Its other dimensions were carefully ascertained, as much theoretic importance had been attached to them ; though to anyone looking at the object itself, the roughness and irregularity of it would put any accuracy of workmanship out of the question. The thickness of the two stones that form it was gauged by means of plumb-lines at 33 points; it varies from 15.16 to 16.20, but the details are scarcely worth printing. This leaf is not simply a flat slab of granite, but on both its upper and lower parts it has a projection on its N. side, about 1 inch thick, where it is included in the side grooves. The edge of this projection down the W. side has been marked out by a saw cut; and the whole of the granite on the inner side of this cut has been dressed away all over the face of the leaf, leaving only one patch or boss of the original surface of the block.

This boss, of which so much has been made by theorists, is merely a very rough projection, like innumerable others that may be seen ; left originally for the purpose of lifting the blocks. When a building was finished these bosses were knocked away (I picked up a loose one among waste heaps at Gizeh) and the part was dressed down and polished like the rest of the stone. It is only in unimportant parts that they are left entire. This boss on the leaf is very ill-defined, being anything between 4.7 and 5.2 wide, and between 3.3 and 3.5 high on its outer face ; at its junction with the block it is still less defined, and might be reckoned anything between 7.2 and 8.2 wide, and 5.6 to 6.6 high. It projects .94 to 1.10 from the block, according to the irregularities of the rough hammer-dressing. Anything more absurdly unsuited for a standard of measure it would be difficult to conceive. I write these remarks with a sharp plaster cast of it before me that I took in 1881. Traces of another boss remain on the W. wall of the Antechamber, above the wainscot; here there has been a boss 12 inches wide and 9 high, which has been knocked away, and the surface rough dressed, though the rest of the face of the stone is ground down elsewhere. The block has been turned in building, so that the flat under-edge of the boss is toward the N. Remains of another boss may be seen on a block in the passage to the King's Chamber; remains of 15 or 16 others in the King's Chamber; 5 others complete in the spaces above that ; and many on the casing of the Third Pyramid and elsewhere (see P1. xii.). The E. to W. breadth of the leaf between its side ledges in the grooves, varies from 40.6 to 41.2 at different heights up the middles of the ledges; but furthermore, the edges are not square, and we may say that 40 to 42 will about represent its irregularity. Yet this was another so-called "standard of measure" of the theorists. The top of the upper block of the leaf is a mere natural surface of the granite boulder out of which it was cut, utterly rough and irregular; and not materially broken away as it dips down deeply into the grooves, and is there plastered over. It varies from 51.24 to 59.0, and perhaps more, below the ceiling. Yet the cubic volume of this block was eagerly worked out by the theorists.

51. The King's Chamber was more completely measured than any other part of the Pyramid ; the distances of the walls apart, their verticality in each corner, the course heights, and the levels were completely observed ; and the results are given in Plate xiii., in which all variations from the mean amounts are shown on their actual size. The principle of concentrated errors enables the eye to grasp at once the character of the variations in workmanship, in a way that no table of figures could show it.

For example, the N. wall is on an average 412.59 inches long (see bottom of P1. xiii.); but the "face of West end" (see left hand of plate) is at the top .18 outside the mean vertical line, and the "face of East end" is .42 inside the mean vertical ; hence at the top the length is actually (.42 - .18) shorter than the mean, i.e., it is 412.35. The line of the ceiling on the W. edge of the N. wall will be seen to be .18 over the mean level of the course, marked "5" at each side of the sheet; and the ceiling line at the E. edge is as much as 1.00 over the same mean level; hence the ceiling slopes .82 on its length along the N. side. Referring now to the floor or to the 1st course, where the mean levels are marked by continuous straight lines all across the diagram, it will be seen how far the variable lines of the "Actual First course" or "Actual Floor" fluctuate up and down, in relation to their mean level; the first course, beginning at the N.W., is at .23 over its mean level (marked 1 at the edge), and runs upward until it is 1.03 over its mean level at the N.E., then down to below mean level at the S.E., then still further down along the S. wall, turning a little up to the S.W. corner, and then rapidly rising to above its mean level again at the N.W. corner, whence we started. Only the first course and floor were directly levelled all round; the upper courses were connected by vertical measures in each corner, hence their fluctuations along the sides were not measured, and they are only marked by broken lines. On looking down, say, the "Face of the West-end" from joint 5 to 4, it is seen that the line bends out, showing the stone to be slightly hollowed ;* but on the average it is about square with the course line; and any error seen in squareness of angle in the diagram, represents only 1/50 of the actual angular error, or 5^{o} equals 6'.

* The middle of the course was only thus offsetted on the top course; the other courses were read on at the top and base of each, to give their errors of cutting and of placing.

Then, below that, it is seen that the line from joint 4 to 3 begins very slightly outside the line from joint 5 to 4; showing that the stone of the 4th course is set back by that amount, owing to error in placing it. Similarly the squareness of faces, and truth of setting of the stones, is shown for all the other courses in each corner. In fact, a paper model, showing all the errors on the actual scale, might be made by cutting out four sides, following the outlines of the faces of the walls as here marked, and bending each side to make it fit to the irregular edge of its adjacent side.

This diagram will represent with quite sufficient accuracy, without numerical tables, the small errors of this chamber; especially as it must be remembered that this shows its actual state, and not precisely its original form. On every side the joints of the stones have separated, and the whole chamber is shaken larger. By examining the joints all round the 2nd course, the sum of the estimated openings is, 3 joints opened on N. side, total = .19; 1 joint on E. = .14; 5 joints on S=.41; 2 joints on W. = .38. And these quantities must be deducted from the measures, in order to get the true original lengths of the chamber. I also observed, in measuring the top near the W., that the width from N. to S. is lengthened .3 by a crack at the S. side.

These openings or cracks are but the milder signs of the great injury that the whole chamber has sustained, probably by an earthquake, when every roof beam was broken across near the South side; and since which the whole of the granite ceiling (weighing some 400 tons), is upheld solely by sticking and thrusting. Not only has this wreck overtaken the chamber itself, but in every one of the spaces above it are the massive roof-beams either cracked across or torn out of the wall, niore or less, at the South side; and the great Eastern and Western walls of limestone, between, and independent of which, the whole of these construction chambers are built, have sunk bodily. All these motions are yet but small-only a matter of an inch or two-but enough to wreck the theoretical strength and stability of these chambers, and to make their downfall a mere question of time and earthquakes.

52. Applying, then, these corrections of the opened joints to the lengths of the lower course -and also, as being the most likely correction, to the upper parts as well-we have the following values for the original lengths of the chamber, and for the error of squareness of the present corner angles.

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
Top	412.14	+ 0' 4"	206.30	– 0' 35"	411.88	+ 1' 35"	206.04	– 1' 4"
Mean	412.40	– 2' 57"	206.29	+ 2' 20"	412.11	– 1' 2"	205.97	+ 1' 39"
Base	412.78	– 4' 54"	206.43	+ 4' 40"	412.53	– 4' 5"	206.16	+ 4' 19"

Now it will be observed that though the lengths can be corrected by the sum of the openings, the angles cannot be so corrected, as we do not know which angle the change of length has affected. Hence the present angles are entered above, with the reservation that the sides having altered about 1 in 1,000 of their length, the original angles may have easily been 3' or 4' different; and, therefore, all that we can say about the angles is, that the builders were probably not 5' in error, and very possibly less than that; also that the errors change sign from base to top, so that each course must be a true right angle at some level up it.

Probably the base of the chamber was the part most carefully adjusted and set out; and hence the original value of the cubit used can be most accurately recovered from that part. The four sides there yield a mean value of **20.632 ± .004**, and this is certainly the best determination of the cubit that we can hope for from the Great Pyramid.

The top course of both the E. and W. walls consists of a single stone; on the N. and S. walls the joints of it were measured thus :-- N. wall, E. end 0, joints 62.1, 248.8; S. wall, E. end 0, joint 189.2.

The average variation of the thickness of the courses from their mean is .051, the mean being 47.045 between similar joints, or including the top course, which was necessarily measured in a different way, 47.040 ± .013.

53. The roof of the chamber is formed of nine granite beams , of the following breadths, the two side beams partly resting on the ends of the chamber :--

	Along N. side.		Along S. side.		Skew.	Difference of end widths.
	Stones.	Total.	Stones.	Total.		
E.		0 - x		0 - x		
	22.4 + x		17.8 + x			
		22.4		17.8	- 4.6	
	45.5		45.8			+ .3
		67.9		63.6	- 4.3	
	52.5		53.0			+ .5
		120.4		116.6	- 3.8	
	49.1		51.0			+ 1.9
		169.5		167.6	- 1.9	
	53.9		55.4			+ 1.5
		223.4		223.0	- .4	
	44.8		45.8			+ 1.0
		268.2		268.8	+ .6	
	58.1		59.3			+ 1.2
		326.3		328.1	+ 1.8	
	62.7		60.8			- 1.9
		389.0		388.9	- .1	
	23.3 + x		23.4 + x			
W.		412.3 + x		412.3 + x		

The column of "skew" shows the difference in the position of the joints on the opposite sides of the chamber; and the "difference of end widths" the variation between the two ends of the same beam. From this table it seems probable that the roofing in of the chamber was begun at the W end, as the skew of the beams increases up to the E. end; and also as the largest beams, which would be most likely to be first used, are at the W. end. The numbering of the slabs in the top space above the King's Chamber also begins at the W. end. Vyse, however, states that these "chambers of construction" were begun

These roofing-beams are not of "polished granite", as they have been described; on the contrary, they have rough-dressed surfaces, very fair and true so far as they go, but without any pretence to polish. Round the S.E. corner, for about five feet on each side, the joint is all daubed up with cement laid on by fingers. The crack across the Eastern roof-beam has been also daubed with cement, looking, therefore, as if it had cracked before the chamber was finished.

At the S.W corner, plaster is freely spread over the granite, covering about a square foot altogether.

54. The floor of the chamber, as is well known, is quite disconnected from the walls, and stands somewhat above the base of the lowest course. It is very irregular in its level, not only absolutely, but even in relation to the courses; its dep!h below the first course joint varying 2.29, from 42.94 to 40.65. This variation has been attributed to the sinking caused by excavation beneath it, but this is not the case; it has been only undermined at the W. end beneath the coffer,* and yet the floor over this undermined part is 1½ inches higher in relation to the first course, than it is at the SE. corner; and along the S. side where it has not been mined it varies 1½ inches in relation to the first course. In these cases I refer to the first course line, as that was the builder's conception of level in the chamber, to which they would certainly refer; but if we refer instead to absolute level, the anomalies are as great and the argument is unaffected.

* I know the hole well, having been down into it more than once.

It appears, then, that the floor never was plane or regular; and that, in this respect, it shared the character of the very variable floor of the passage that led to the chamber, no two stones of which are on the same level. The passage floor, even out to the great step in the gallery, is also inserted between the walls, like the floor of the chamber.

55. Among peculiarities of work still remaining, are the traces of 15 bosses or lugs on the faces of the granite blocks , all on the lower course. Those best seen are two on the fourth block of the N. wall, counting from the door; they have been about 12 inches wide and the same high, 14 inches apart, and their flat bottom edges 3 inches from the base of the block (see P1. xii.). They may be very plainly seen by holding a candle close to the wall below them; this shows up the grinding around them, and the slight projection and very much less perfect grinding of the sites of the bosses. There is a remarkable diagonal drafted line across the immense block of granite over the doorway; it appears not to run quite to the lower corner on the E. side; but this is doubtless due to the amount by which the block is built into the E. wall, thus cutting off the end of the diagonal line. This sunken band across the stone appears to have been a true drafted straight line cut in process of working, in order to avoid any twist or wind in the dressing of the face; this method being needful as the block was too large to test by the true planes otherwise used (see section 135).

The position of the King's Chamber in the Pyramid is defined thus: N. wall at base 330.6 ± .8 S. of centre of Pyramid; S. wall **537.0 ± .8** from centre; E. wall (284.4 ± 20.7) = 305.1 ± 3.0 E. of centre; W. wall 107.7 ± 3.0 W. of centre. Base of walls **1686.3 to 1688.5 ± .6** above pavement; actual floor 1691.4 to 1693.7 ± .6 above pavement; ceiling 1921.6 to 1923.7 ± .6 above pavement.

56. The air channels leading from this chamber have been already mentioned (see section 24) and reference has been made to P1. xi. for the positions of their outer ends. The angles of them had not yet been accurately measured, and therefore I carefully observed them by a sliding signal and a theodolite. The angles on the floors of them at different distances from the theodolite station at the present outer ends are thus :--

N. Channel.		**S. Channel.**	
At 84 to 180	32º 4' 45"	At 0 to 120	45º 25' 6"
At 180 to 300	31º 37' 15"	At 120 to 240	45º 30' 7"
At 300 to 372	30º 43' 15"	At 240 to 360	45º 25' 57"
Mean	31º 33'	At 360 to 480	45º 25' 14"
		At 480 to 600	45º 15' 19"
		At 600 to 720	45º 7'42"
		At 720 to 840	44º 26' 18"
		Mean	45º 13' 40"

For example, on the floor of the N. channel, the angle on the part from 180 to 300 inches from the mouth averages 31º 37' 15"; this is, of course, quite apart from whatever the dip may be from the passage mouth to those points; and it is reduced from the actually observed quantities. The above list of angles are just equiva]ent to observations by a clinometer, sliding to different parts of the passage. It is striking that the slope of both passages continuously increases up to the outside (except just at the mouth of the S. channel) ; hence these quantities, which only extend over a part of either passage, cannot give the true mean slope; probably on the whole length the means would not be greater angles than 31º and 44½º respectively.

The N. channel has been forced open as a working passage for some way inwards, only leaving the floor and W. side perfect. The channel is now blocked, just below the end of the enlarged part, and on working a rod 4½ feet into the sand, it ran against limestone. The sand in the hole has blown in during gales, which sweep up sand like mist. The remains of the original channel show it to have varied from 8.9 to 9.2 (mean 9.0) in width, and to have been 8.72 and 8.74 in height.

The S. channel is blocked by sand at 76 feet down. It is not straight in the clear length, curving more than its own width to the east; and the sides often shift a few tenths of an inch in passing from one stone to another. These details were seen by examining it with a telescope on Feb. 8, and by photo-graphing it on Nov 2, 1881; these being the days on which the sun shines down it at noon. Its width at the top is 8.35 and 8.65, and its height 8.7 to 8.9.

57. The coffer in the King's Chamber is of the usual form of the earliest Egyptian sarcophagi, an approximately flat-sided box of red granite. It has the usual under-cut groove to hold the edge of a lid along the inside of the N., E., and S. sides; the W. side being cut away as low as the groove for the lid to slide over it; and having three pin-holes cut in it for the pins to fall into out of similar holes in the lid, when the lid was put on.
It is not finely wrought, and cannot in this respect rival the coffer in the Second Pyramid. On the outer sides the lines of sawing may be plainly seen: horizontal on the N., a small patch horizontal on the E., vertical on the S., and nearly horizontal on the W.; showing that the masons did not hesitate at cutting a slice of granite 90 inches long, and that the jewelled bronze saw must have been probably about 9 feet long. On the N. end. is a place, near the W. side, where the saw was run too deep into the granite, and was backed out again by the masons; but this fresh start they made was still too deep, and two inches lower they backed out a second time, having altogether cut out more than 1/10 inch deeper than they intended. On the E. inside is a portion of a tube drill hole remaining, where they tilted the drill over into the side by not working it vertically. They tried hard to polish away all that part, and took off about 1/10 inch thickness all round it; but still they had to leave the. side of the hole 1/10 deep, 3 long, and 1.3 wide; the bottom of it is 8 or 9 below the original top of the coffer. They made a similar error on the N. iriside, but of a much less extent. There are traces of horizontal grinding lines on the W. inside. Reference should be made to section 129 for the subject of stone-working in general.

58. The coffer was very thoroughly measured, offsets being taken to 388 points on the outside, to 281 points inside, or 669 in all; besides taking 281 caliper measures.

Before raising it from the floor to measure the bottom, its place as it stood on the chamber floor, tilted up at the S. end by a large pebble under it, was observed thus :--

	N.E. to N. wall	N.W. to N.	N.W. to W.	S.W. to W.	S.W. to S.	S.E. to S.
Top	47.70	48.90	53.34	56.50	67.92	(68.60)
Base	48.35	50.06	53.32	56.54	67.62	68.06

S.E. to S. wall in brackets, was taken at 10 below top, owing to breakage above that.

On raising the coffer no trace of lines was to be found to mark its place on the floor, nor any lines on the floor or bottom of the coffer.

The flint pebble that had been put under the coffer is important If any person wished at present to prop the coffer up, there are multitudes of stone chips in the Pyramid ready to hand. Therefore fetching a pebble from the outside seems to show that the coffer was first lifted at a time when no breakages had been made in the Pyramid, and there were no chips lying about. This suggests that there was some means of access to the upper chambers, which was always available by removing loose blocks without any forcing. If the stones at the top of the shaft leading from the subterranean part to the gallery had been cemented in place, they must have been smashed to break through them, or if there were granite portcullises in the Antechamber, they must also have been destroyed; and it is not likely that any person would take the trouble to fetch a large flint pebble into the innermost part of the Pyramid, if there were stone chips lying in his path.

59. The measurements of the coffer surfaces by means of offsets from arbitrary lines, have all been reduced in both tilt and skew, and are stated as offsets or variations + and -- (i.e., in excess or deficiency of stone) from a set of mean planes. These mean planes, then, are supposed to lie half in and half out of the stone, being in the mean position and direction of the face. The mean planes adopted for the E. and W. sides, both in and out, are all parallel; hence variations from these planes represent errors of flatness of the surfaces, and also errors of parallelism of the quasi-parallel surfaces. The mean planes adopted for the N. and S. ends, both in and out, are similarly all parallel.

The mean planes adopted for the bottom, both in and out, and the top, are also patallel These mean planes of the E. and W. sides, and of the N. and S. ends, are all square with the planes adopted for the bottom and top. There is no exception from parallelism in the system of comparison planes; and but one exception from squareness, in that the N. and S. planes are not adopted square with the E. and W. planes. There was such difference from squareness in the work, that to make the planes square with each other, would have altered the offsets so much as to disguise the small curvatures of the faces; and adopting the planes slightly out of square, makes no difference in taking out quantities of length, surface, or bulk, from the tables of offsets.

The mean planes to which the coffer surfaces are referred here, and from which the actual surfaces differ by an equal amount + and -- , yield the following dimensions : --

N. end thick	5.67	E. side thick	5.87	Inner depth	34.42
Inside length	78.06	Inside width	26.81	Base thick	6.89
S. end thick	5.89	W. side thick	5.82	Outer height	41.31
Outside length	89.62	Outside width	38.50	Ledge depth	1.70

The vertical planes all square with the horizontal; but N. and S. planes cut E. and W. planes at 89° 47' at N.E. and SW. corners, and at 90° 13' at N.W. and S.E. corners.

For convenience of reference the whole coffer was divided by imaginary lines or planes, 6 inches apart in each direction, and represented by rows of chalk spots during the actual measurements. Thus at the S. end the first vertical plane across the coffer from E. to W. is A, through the midst of that end; the second plane is B, which passes 3 inches clear of the end ; then C; and so on to 0, which is 3 inches clear of the N. end; and P the last line, through the midst of the N. end. Then at the W. side the first plane is α , the second β, an inch clear of the side, then γ, δ, ε, ζ ∈ ,an inch clear of the E. side, and η through the E. side. Then vertically the plane *b* is 4 inches above the inside bottom, and *c, d; e, f* are at six-inch intervals ; occasionally, in the most perfect parts, another line, *g* , could be measured on the outside, just at the top. The inside plane, α , was taken at only 3 inches below *b* , or 1 inch over the bottom; but the outside plane, α , was taken the full six inches below *b* , i.e., 4 or 5 inches above the outside bottom. In taking means in the inside the offsets to α are only allowed half weight, as they belong to a much shorter space than the others; they ought, theoretically, to have even less weight, but as the inner planes gather in rapidly, just at the bottom below α , this half weight probably gives the truest results.

Having, then, adopted the above mean planes for the sides, and divided them for reference at every six inches, we can state all the variations of the actual surfaces as being either + (i.e., an excess of stone beyond the plane) or -- (i.e., a deficiency of stone), either inside or outside the coffer.

These variations are as follow, stated in hundredths of an inch :--

OUTSIDE OF COFFER

South end.																**North end.**
		A	b	C	D	E	F	G	H	J	K	L	M	N	O	P
Top	*g*					+2							-1	-3		
	f	+10	+8	+8	+4	+3	-4	+1	+1	0	-1	-3	-1	0	+1	-1
West	*e*	+12	+7	+14	+5	+1	-1	-5	-6	-8	-10	-12	-8	-5	+3	+5
outside	*d*	+14	+8	+12	+9	+1	-7	-13	-14	-16	-14	-15	-12	-8	+1	+1
	c	+17	+10	+10	+9	+6	-2	-8	-11	-13	-13	-13	-10	-6	0	+3
	b	+20	+10	+9	+9	+2	-4	-9	-10	-14	-12	-11	-7	0	+8	+12
Base	*a*	+21	+10	+9	0	-6	-8	-9	-8	-6	-2	+2	+10	+17	+26	+31

South end.																**North end.**
		A	b	C	D	E	F	G	H	J	K	L	M	N	O	P
Top	*g*	much										+5	+8	+9	+9	
	f	broken			-7	-5	-4	-3	0	+1	+2	+4	+7	+7	+7	+9
East	*e*	away		-8	-6	-5	-3	-2	0	0	+2	+2	+5	+5	+4	+7
outside	*d*	-13	-11	-7	-5	-4	-3	0	+1	+1	+3	+2	+5	+5	+5	+8
	c	-12	-11	-8	-7	-5	-3	-2	+1	+1	+2	+2	+6	+6	+5	+8
	b	-12	-12	-8	-7	-4	-4	-1	+1	+1	+2	+3	+7	+7	+7	+8
Base	*a*	-9	-9	-7	-4	0	+1	+1	+2	+3	+4	+5	+8	+8	+5	+6

West side								**East side**
		α	β	γ	δ	ε	ζ	η
Top	*g*		+39	+35			+21	
	f	+15	+31	+29	+21	+21	+20	+18
North	*e*	+16	+9	+3	-2	+1	+7	+13
outside	*d*	+13	-2	-14	-21	-15	-6	+2
	c	+5	+2	-10	-17	-9	-2	+3
Base	*b*	-3	-3	-3	-9	-8	-4	+2
	a	-6	-12	-20	-36	-27	-4	+13

West side								**East side**
		α	β	γ	δ	ε	ζ	η
Top	*g*							
	f	-12	-7	+1	+2	+7	+24	+34
South	*e*	-12	-12	-9	-4	+3	+22	+34
outside	*d*	-21	-24	-16	-11	-2	+22	+37
	c	-25	-27	-21	-15	+1	+22	+41
Base	*b*	-27	-30	-10	-14	-4	+26	+47
	a	-22	-32	-16	-13	-2	+29	+54

South end.																**North end.**
		A	b	C	D	E	F	G	H	J	K	L	M	N	O	P
West.	α			+15	+15	+17	+13	+12	+16	+11	+5	+1	-7	+9	+4	
	β			+20	+15	+16	+9	+14	+4	+6	-1	-11	-3	+4	-1	
	γ			+22	+22	+19	+8	+8	-2	+1	-4	-9	-18	-4	-8	
Bottom	δ		+10	+17	+21	+9	+3	-3	-4	-6	-11	-16	-15	-9	-12	
outside	ε		+9	+17	+12	+7	+1	-8	-12	-11	-13	-25	-12	-10	-15	
	ζ		+13	+7	+12	+4	+2	-6	-7	-12	-8	-17	-12	-20		
East.	η		-8	+8	+5	+4	+7	-5	-8	-13	-12	-10	-14	-15		

INSIDE COFFER

South end.														**North end.**
		b	C	D	E	F	G	H	J	K	L	M	N	O
Top	*f*	+3	+1	+2	+7	+7	+7	+4	+2	+2	+3	-12	-1	+1
	e	-1	+1	+2	+4	+6	+7	+2	+4	+4	+4	+2	-1	-1
West	*d*	+1	+2	+4	+4	+3	-1	-6	-5	-4	+1	0	0	-2
inside	*c*	-1	+1	+3	+3	+5	+1	-7	-11	-11	-3	-3	-1	0
	b	+4	+1	+1	+2	+6	+10	-2	-12	-16	-9	-5	-2	-1
Base	*a*	+19	+3	+2	+1	+5	+10	-2	-10	-8	+3	+6	+5	+4

South end.														**North end.**
		b	C	D	E	F	G	H	J	K	L	M	N	O
Top	*f*	-5	+1	+2	+7	+7	+7	+4	+2	+2	+3	-12	-1	+1
	e	-5	+1	+2	+4	+6	+7	+2	+4	+4	+4	+2	-1	-1
East	*d*	-4	+2	+4	+4	+3	-1	-6	-5	-4	+1	0	0	-2
inside	*c*	+-6	+1	+3	+3	+5	+1	-7	-11	-11	-3	-3	-1	0
	b	-6	+1	+1	+2	+6	+10	-2	-12	-16	-9	-5	-2	-1
Base	*a*	0	+3	+2	+1	+5	+10	-2	-10	-8	+3	+6	+5	+4

West side.						**East side.**
		β.	γ.	δ.	ε.	ζ.
Top	**f**	0	-7	+1	+2	+4
	e	0	-8	-3	-6	-8
North	**d**	0	-2	0	-1	-5
inside	**c**	-3	-3	-1	+1	-1
	b	+1	+1	-1	-1	+2
Base	**a**	+20	+16	+18	+10	0

West side.						**East side.**
		β.	γ.	δ.	ε.	ζ.
Top	**f**	+3	0	-1	-2	-10
	e	-5	-5	-4	-5	-9
South	**d**	-4	-3	-1	-1	-5
inside	**c**	+1	0	+2	+2	-4
	b	-5	+1	+4	+4	+2
Base	**a**	+11	+13	+24	+23	+17

South end.								**North end.**						
		b	C	D	E	F	G	H	J	K	L	M	N	O
West.	β	-1	-3	+5	0	-4	+1	+8	+5	+1	+10	+9	+11	+4
	γ	-8	-5	-3	-18	-5	0	-2	+1	-5	-2	+5	+1	0
Bottom inside.	δ	-5	-6	-4	-1	+2	+2	+2	0	-2	0	+1	-2	+7
	ε	+12	-9	+9	-6	+6	-13	-2	-1	-2	+1	0	-15	-12
East.	ζ	+2	+5	+3	+2	+5	+19?	+2	+1	+11	-4	+1	-5	0

TOP OF COFFER

South end.									**North end.**								
		A	b	C	D	E	F	G	H	J	K	L	M	N	O	P	Actual top.
West.	α		[0]	[+1]	[+4]	[+2]	[+4]	[+5]	[+4]	[+7]	[+6]	[+6]	[+5]	[+8]	[+8]		
	β	[-2]														[-1]	
	γ															[0]	
	δ															[+1]	
Top.	ε															[0]	
	ζ															[-3]	-1
	η									[-4]	[-4]	[-1]	[0]	[+4]	[0]	[-8]	
East.							act	ual	top		-4	-4		0	+1		-3

Offsets in brackets are from points on the cut out ledge, raised 1.70 inches, which is the mean level of the ledge below adjacent points of the remaining top; thus restoring the top as nearly as may be from the ledge. The actual top only remains at six points.

If; for example, the length of the E. side of the coffer is wanted, from the foregoing tables, at the level of *d*, half way up; on referring to " North outside" and "South outside" it will be seen that at *d* on East side the coffer is in excess of the mean length by + .02 on N. and + .37 on S.; adding these to the mean length (89.62 + .02 + .37) = 90.01 is the result for the E. outside of the coffer half way up. Similarly at 8 inches under the top on the same side, at *f* it is (89.62 + .18 + .34) = 90.14 in length; or at 4 inches above the bottom (which is about the lowest point uninjured) it is at α (89.62 + .13 + .54) = 90.29 in length. Or if the inside width is wanted, half way up the N. end, at *d*; referring to "West inside" and "East inside," at North end, *d* level, it is seen to be the mean inner width, 26.81, --12 on W., +.02 on E. = 26.71 ; the signs being, of course, reversed in adding internal offsets together. Similarly at the middle of the length of the coffer (H, *d*) the internal width is 26.81 + .06 + .05 = 26.92

If the thickness of the middle of the bottom is wanted, referring to "Bottom outside" and "Bottom inside," at H, *d* it is seen that the mean thickness 6.89 is changed by -- .04 and +.02, and it is therefore 6.87 thick at that point Or if the thickness of the middle of the N. end is wanted at d and *d* referring to "North outside" and "North inside," it is seen to be (5.67 -- .21 + 0) = 5.46 or the middle of the N. end at the top is (5.67 + .21 + .01) = 5.89 Thus the dimensions internal or external, or the thickness of any part, can be easily extracted from the tables by merely adding the corresponding offsets to the mean dimension.

60. The thicknesses of the sides, however, are involved in the measurement of the cubic bulk of the coffer , and therefore need to be very accurately known, in order to test the theories on the subject. And by the above method the thickness is dependent on the combination of many separate measures, and is, therefore, subject to an accumulation of small errors. To avoid this uncertainty, the sides were independently calipered ; observing at every six inches, on the same spots on which the offsets were read. And it is to these caliperings which follow that I would mainly trust for determining the solid bulk of the coffer. The thickness is stated in hundredths of an inch.

South end.														**North end.**
		b	C	D	E	F	G	H	J	K	L	M	N	O
Top thickness of West side Base	*f*	598	599	587	593	597	604	593	597	599	597	600	599	598
	e	592	597	583	579	586	584	580	579	582	585	590	590	597
	d	595	591	594	590	578	568	561	561	570	577	581	589	597
	c	596	589	592	588	576	561	555	553	559	571	579	591	596
	b	600	590	592	582	561	548	541	542	553	571	587	594	593
	a	617	613	602	582	576	557	548	576	586	602	607	619	610
Means		598	595	591	586	579	572	564	570	573	581	590	591	598

South end.														**North end.**
		b	C	D	E	F	G	H	J	K	L	M	N	O
Top thickness of East side Base	*f*				592	594	594	594	594	596	597	582	600	597
	e		583	587	589	593	594	593	579	595	596	596	594	595
	d	575	585	588	589	597	587	586	586	591	594	597	596	596
	c	571	581	587	587	592	590	584	583	581	589	593	596	596
	b	572	583	586	590	591	597	591	579	577	586	591	595	596
	a	591	587	592	591	598	603	597	601	601	597	602	599	613
Means		575	585	588	590	594	593	590	589	589	593	592	596	597

West side.						**East side.**
		β. €	γ.	δ.	ε.	ζ.
Top thickness of North end Base	*f*	596	583	589	589	595
	e	574	561	564	560	571
	d	569	548	549	552	559
	c	564	553	551	560	567
	b	567	561	553	563	572
	a	580	578	563	561	570
Means		574	563	561	564	573

West side.			East side.			
		β. ∈	γ.	δ.	ε.	ζ.
Top	*f*	591	595			
thickness	*e*	579	585	588	593	
of	*d*	567	575	572	587	600
South end	*c*	564	573	575	588	604
Base	*b*	562	570	576	587	609
	a	584	595	601	615	638
Means		574	581	584	594	609

From these caliperings the mean thickness of each of the sides, as compared with the results of the offsets, are thus :--

		By calipers	By Offsets	Difference
Thickness of	N.	5.67	5.67	0
	E.	5.90	5.87	-.03
	S.	5.88	5.89	+.01
	W.	5.84	5.82	-.02

Hence there appears to be a constant error of - .01 on an average, making the result of the thickness by the offsets to be less than the truth. This may be due to a tendency to read the offsets too large, or else possibly to a slight skewing of the calipers, as 3° skew would make this difference on 6 inches.

To compare in detail the results by calipers and offsets, over a small space, let us take the thickness of the N. end, along the lines C and d, which are near the mid height :--

		β ∈ ∈	γ	δ	ε	ζ
At *d*	by offsets	5.65	5.51	5.46	5.51	5.56
	by calipers	5.69	5.48	5.49	5.52	5.59
At c	by offsets	5.66	5.54	5.49	5.59	5.64
	by calipers	5.64	5.53	5.51	5.60	5.67

Thus the mean difference between the thicknesses as ascertained by the two methods is .022, with a constant difference in one direction of .012 on an average. The spots observed on in the two methods were not always exactly identical; and so some difference may be due to waves of short length in the surface of the stone.

In stating the offsets on the top, the mean plane adopted is not the simple mean of all the offsets, but the mean of diagonally opposite pairs of offsets, so far as they can be taken. This is necessary in order to obtain a true result, as otherwise (the top being broken away all at one corner) any great tilt that it may have had, in relation to the base planes, would vitiate the result.

61. From the foregoing data the cubic quantities may be calculated of a simple rectilineal box, omitting all notice of the attachments for the lid, employing the mean planes :--

Contents-- 72,030; solid bulk = 70,500; volume over all, 142,530 cubic inches. Or by the caliper results, instead of the mean planes, the bulk is 1/580 more, and the contents probably about 1/1000 less; hence the quantities would be :--

Contents = 71,960; solid bulk = 70,630; volume over all, 142,590.

These quantities have a probable error of only about 60 cubic inches on contents and volume, and 100 inches on the bulk. The bulk of the bottom is = 23,830; and hence one side and end is on an average = 23,335. Bulk of bottom x 3 is then = 71,490; and 3/2 x bulk of sides and ends = 70,000, subject to about 100 cubic inches probable error.

62. The spaces, or "chambers of construction," as they have been called, which lie one over the other above the King's Chamber, are entered from a small passage which starts in the E. wall of the gallery, close under the roof. This is apparently an original passage, and leads into the lower chamber; the other four spaces above that can only be entered by the forced ascent cut by Col. Howard Vyse. This latter passage is not so easy to go up as it might be, as it is nearly all in one continuous height, so that a slip

at the top chamber means a fall of thirty feet; and as there are no foot-holes, and the shaft is wide, and narrows upwards, an Arab guide of Dr. Grant's refused to venture up it, alleging that he had a wife and family to think of. Ah Gabri, however, was quite equal to the business, and held a rope ladder to help me, which he and I together held for Dr. Grant.

The mouth of the passage out of the top of the gallery is 26.3 wide horizontally at top, 26.2 at base, the S. side of it being formed by the topmost lap of the S. end of the gallery. The top and base of the mouth follow the slope of the gallery, the top being the top of the gallery, and the base the bottom of the topmost overlapping; thus the mouth is 29.4 high, square with the gallery. The rough passage is 28½ wide, 32 inches high, and over 20 feet long.

All these chambers over the King's Chamber are floored with horizontal beams of granite, rough dressed on the under sides which form the ceilings, but wholly unwrought above. These successive floors are blocked apart along the N. and S. sides, by blocks of granite in the lower, and of limestone in the upper chambers, the blocks being two or three feet high, and forming the N. and S. sides of the chambers. On the E. and W. are two immense limestone walls wholly outside of; and independent of; all the granite floors and supporting blocks. Between these great walls all the chambers stand, unbonded, and capable of yielding freely to settlement. This is exactly the construction of the Pyramid of Pepi at Sakkara, where the end walls E. and W. of the sepulchral chamber are wholly clear of the sides, and also clear of the sloping roof-beams, which are laid three layers thick; thus these end walls extend with smooth surfaces far beyond the chamber, and even beyond all the walls and roofing of it, into the general masonry of the Pyramid.

The actual dimensions of these chambers are as follow :--

	N	E	S	W
Top	462 to 470	...	468.4	247
4th	481	196	467	198
3rd	479 ?	...	472	198
2nd	...	204.65	471.8	...
1st	460.8	205.8	464.6	205.9
Kings	412.8	206.4	412.5	206.1

But these dimensions are merely of the rough masonry; and some lengths could not be measured owing to the encumbrance of blocks of stone and rubbish left in the chambers from Vyse's excavations.

63. In the first chamber the S. wall has fallen outwards, dragging past some of the roof-beams, and breaking other beams at the S.E. corner. The E. and W. end walls have sunk, carrying down with them the plaster which had been daubed into the top angle, and which cracked freely off the granite roofing. On the E. end one block is dressed flat, but all the others are rough quarried.

In the second chamber are some bosses on the N. and S. wall stones; and several of the stones of the N. wall are smoothed, and one polished like those in the King's Chamber, seeming as if some spare blocks had been used up here. The S.E. corner shows cracks in the roof .52 wide. The masons' lines, drawn in red and black, are very remarkable in this and the upper chambers, as they show, to some extent, the methods of working. Some of the lines in this chamber, drawn in red on the S. wall blocks of granite, are over some of the plastering, but under other parts of the plaster. These lines, therefore, were drawn during the building, and while the plaster was being laid on, and slopped like whitewash into the joints. The red lines are always ill-defined and broad, about ¼ to 1½ inch; but, to give better definition, finer black lines were often used, either over the red or alone, about 1/10 inch wide. On the S. wall, starting from a drafted edge on the W. wall, 4 inches wide, there is a vertical mason's- line at 22.3, a very bad joint at 51.5, another line at 70.5, another at 435.8, and the E. wall at 471.8. Thus the two end lines are 413.5 apart, evidently intended for the length of the King's Chamber below them, and define the required limits of this upper space. On the E. wall is a vertical mid-line drawn, with a cross line and some signs; from this mid-line to a line at the S. end is 101.8, and to a line at the N. end of the wall is 102.85 ; total, 204.65, intended for King's Chamber width. There is a large cartouche of Khnumu-Khufu, nearly all broken away by Vyse's forced entrance; but this and other hieroglyphs need not be noticed here, as they have been already published, while the details of the masons' marks and lines of measurement have been neglected.

In the third chamber, the N. and S. sides are of granite as before; but they rest on pieces of limestone, put in to fill up hollows, and bn'ng them up to level: this showing, apparently, that the stock of granite supporting blocks had begun to run short at this stage of the building, and that any sort of pieces were used up, being eked out by limestone, which in the upper chambers supplied their places altogether. The flooring beams are very unequal in depth. and hence the sides of many of them are exposed, and show us the masons' marks. On the 1st beam from the E. end is a mid-line on the W. face at 98 from the S. On the 4th beam is a mid-line on the E. face, 102.8 to N., and 101 to S. On the 6th beam is a mid-line on W. face, 100 to N. and 101.5 to S.; these N. and S. ends being merely the rough sides of the chamber. There are two bosses on the S. side of the chamber. The chamber sides are much slopped over with liquid plaster. On the N. side is a vertical line on the western granite block, over the edge of a limestone block beneath it, apparently to show the builders where to place it. From the W. end of the chamber this line is at 10 inches, joints at 210 and 246, a red line at 260, chamber end at 479 (?), and end of granite blocks at 503.

In the fourth chamber the supporting blocks along the N. and S. sides are all of limestone, and are much cracked and flaked up by top pressure. The great end walls, between which all these chambers stand, have here sunk as much as 3 inches in relation to the floors and sides; as is shown by the ledges of plaster sticking to them, which have originally fitted into the edges of the ceiling. The roof-beam by the forced entrance has been plastered over, then coloured red, and after that accidentally splashed with some thin plastering. Along the N. wall, from the E. end of the floor as 0, there is a line at 37.8, another at 58.5 another at 450.6, and the W. end at 481 thus the extreme lines are 412.8 apart, with a supplemental line at 20.7 from one of them. This last was probably put on in case the end line should be effaced in building, so that the workmen would not need to remeasure the whole length. One stone, 65 inches long, has a mark on it of "3 cubits."
On the S. wall, from the E. end = 0, there is a line at 32.6, another at 384.7, another at 446.5, and the W. end at 467; here the extreme lines are 413.9 apart, with a supplemental line 61.8 (or 3 X 20.6) from one end. Along both sides of the chamber is a red line all the way, varying from 20.6 to 20.2 below the ceiling; with the vertical lines just described crossing it near each end. Remembering the Egyptian habit of building limestone courses in the rough, and marking a line to show to where they were to be trimmed down level, this line seems to have been put on to regulate the trimming down of these lime- stone sides; either as a supplemental line, like those one cubit from the true marks on tbe granite beams, or else placed a cubit lower than the trimming level, in order that it should not be effaced in the cutting. On the E. floor-beam is a line 98.6 from the S. end. On the third beam is a line 100 to N. and 96.2 to S. end. On the 4th beam a line 98.3 to N., and 100.6 to S. end. On the sixth beam a horizontal line running all along it, with a mid-line 98.0 to N. and 98.1 to S. end; and a supplemental line at 20.3 to 20.6 from S. end. On the other side of the beam a line is at 98.1 to N. and 96 to S. end. The rough tops of the floor-beams of this chamber show most interestingly the method of quarrying them; exactly as may be seen on the rough tops of the granite roofing inside the Third Pyramid. On the top of each stone is a hollow or sinking running along one edge; and branching from this, at right angles across the stone, are grooves 20 to 25 inches apart, about 4 wide, and 1½ deep. These seem to show that in cutting out a block of granite, a long groove was cut in the quarry to determine the trend or strike of the cleavage ; and then, from this, holes were roughly jumped about 4 inches diameter and 2 feet apart, to determine the dip of the cleavage plane. This method avoids any danger of skew fractures, and it has the true solidity and certainty of old Egyptian work.

In the fifth or top chamber, the width is quite undefined; and we can only say that between the points where the sloping roof-slabs appear is 247 inches. The roof-slabs have separated at the apex 1.55 at E. end, and I.0 at W. end. The end walls are very rough, being merely the masonry of the core. On the second floor-beam are two horizontal lines 20.6 to 20.7 apart, with three vertical lines across them, 103.1 and 103.5 apart. They have triangles drawn in black on both the vertical and horizontal lines, the triangle on the horizontal being 12.5 from the end vertical line, and therefore not apparently at any exact distance along it. On the fourth beam from the E. is a horizontal line on its W. side, with four vertical lines: these are a mid-line, others at 102.6 and 102.6 from it, and a supplemental line 20.0 from one of these. On the E. side of the same is a horizontal and three vertical lines; the two end ones 206.3 apart, and a supplemental line 2I.0 from one end. Both of these horizontal lines have a small black triangle, with one side on the line. The third beam from the E. has four verticals, with a triangle beyond the last. These are 103.3 and 103.25 from a mid-line, with a supplemental line 20.95 from one end. The E. beam has five verticals, 103.0 and 102.7 from the mid-line, with supplemental lines at 20.7 and 19.4 from the ends; it has also a horizontal line, with a large red triangle on the lower side of it, and a smaller black triangle inside the red. On the S. side is a line 29.3 from the W. end, apparently one terminal of the 412 -inch length. The roofing-beams are all numbered, beginning at the W. end of the N. side, going along to the E., turning to the S. side, and so back to the W. end. The numbers visible on the under-sides of the beams are 4, 18, 21, and 23 ; probably the numbers of the others are on the sides now covered.

From all these details of the lines, it seems that the roofing-blocks had usually a mid-line and two end lines marked on their sides as a guide in placing them; and, in case of obliteration, extra lines were provided, generally a cubit (20.6) from each end, but sometimes at other points. The horizontal lines were probably to guide the workman in cutting the straight under-sides of the beams; and it would be desirable to measure through some cracks to find their distances from the ceiling side. The flooring of the top chamber has large holes worked in it, evidently to hold the butt ends of beams which supported the sloping roof-blocks during the building.

64. General summary of the positions inside the Great Pyramid :---

	Horizontally		Vertically	
	From N. Base	From Centre	E. from Centre	Above Pavement
Beginning of entrance	**524.1 ± .3**	**N. 4010.0 ± .3**	**mid. 287.0 ± .8**	**+ 668.2 ± .1**
S. end of entrance passage	**4228.0 ± 2.**	**N. 306.0 ± 2.**	**mid. 286.4 ± 1.**	**- 1181.0 ± 1.**
S. end of N. subterranean passage	**4574.0 ± 2.**	**S. 40.0 ± 2.**	**mid. 286.3 ± 1.**	**- 1178.0 ± 1.**
Subterranean Chamber, centre	**4737.0 ± 2.**	**S. 203.0 ± 2.**	**mid. 25.9 ± 2.**	**- 1056.0 ± 2.**
N. end of S. subterranean passage	**4900.0 ± 2.**	**S. 366.0 ± 2.**	**mid. 284.9 ± 1.**	**- 1219.0 ± 1.5**
S. end of S. subterranean passage	**5546.0 ± 3.**	**S. 1012.0 ± .3**	**mid. 277.1**	**- 1213.0 ± 2.**
Beginning of Ascending passage	**1517.8 ± .3**	**N. 3016.3 ± .3**	**mid. 286.6 ± .8**	**+ 179.9 ± .2**
End of Ascending passage	**2907.3 ± .8**	**N. 1626.8 ± .8**	**mid. 287.0 ± 1.5**	**+ 852.6 ± .3**
Queen's Chamber, N.E. corner	**4402.1 ± .8**	**N. 102.0 ± .8**	**side 308.0 ± 3.**	**+ 834.4 ± .4**
Queen's Chamber, mid W. roof	**4533.8 ± .8**	**N. .3 ± .8**	**side 72.0 ± 3.**	**+ 1078.7 ± .6 roof**
Gallery, virtual S. end, floor	**4595.8 ± .9**	**S. 61.7 ± .9**	**mid. 284.4 ± 3.**	**+ 1689.0 ± .5**
Gallery, top of step face	**4534.5 ± .9**	**S. .4 ± .9**	**mid. 284.4 ± 3.**	**+ 1694.1 ± .7**
Antechamber, N. end, floor	**4647.8 ± .9**	**S. 113.7 ± .9**	**same ?**	**+ 1692.6 ± .6**
Antechamber S. end, roof	**4763.9 ± .9**	**S. 229.8 ± .9**	**same ?**	**+ 1841.5 ± .6 roof**
King's Chamber, floor	**4865.0 ± .9**	**S. 330.9 ± .9**	**mid. same**	**+ 1692.8 ± .6**
King's Chamber, N.E. wall base	**4864.7 ± .9**	**S. 330.6 ± .9**	**side 305.0 ± 3.**	**+ 1688.5 ± .6**
King's Chamber, roof				**+ 1921.6 ± .6 to + 1923.7 ± .6**

NOTES

"The Great Pyramid has lent its name as a sort of by-word for paradoxes; and, as moths to a candle, so are theorisers attracted to it. The very fact that the subject was so generally familiar, and yet so little was accurately known about it, made it the more enticing; there were plenty of descriptions from which to choose, and yet most of them were so hazy that their support could be claimed for many varying theories." SIR FLINDERS PETRIE

Sir Flinders Petrie's 1880/82 survey of the Giza plateau which included the GREAT PYRAMID of KHUFU and the relatively unknown TRIAL SITE is probably the most detailed Egyptian study ever undertaken by a surveyor.

This is the original edition of 1883 which was sold out during the first few months. The second edition which summarized many of the tables into a few lines and omitted much of the technical work appeared in early 1885.

Petrie's approach to the 1880/82 survey is seen as something quite extraordinary and it warrants the remarks he sometimes made about the "rough and ready" character of those preceding him. For example when measuring the Great Pyramid's descending passageway Petrie refers to his encounter with screw-driver marks.

For those who have taken time to study some of the surveys conducted on the Giza plateau, Petrie's contribution stands head and shoulders above the rest. Whether he is right or wrong in all his readings is not the issue ... he just did things better.
After his extensive triangulation on the Giza plateau Petrie was somewhat taken back by what he uncovered and said of the Great pyramid "a triumph of skill. Its errors, both in length and in angles, could be covered by placing one's thumb on them."

Petrie measured everything in inches, a 10th of an inch, a 100th of an inch and occasionally a 1000th of an inch. It was acceptable then ... and it should still be acceptable now.
He went to Egypt as a professional surveyor but he also had experience as a mechanical engineer and his interest in metrology was written into a number of previous books.

Some of the book's type is sprinkled with dramatic dashes, words for example that appear as;---the Sphinx---and ---Mr Gill. They are not overdone and so have been retained more or less as they appear in the text. For appearance sake however, the book's italics has been converted to the alternate underline, although in some instances (where a reference has been made) this has not been necessary. Providing the fonts **MS Sans Serif** and **Arial** are both available the text shows little difference between browsers although IE5 probably gives the better reading . Additionally, some words of the book have come up poorly in the scan and might occasionally appear with ~ in place of a letter or letters, in particular (and with much annoyance) the decimal place or the "period" (for English speaking countries). Every effort has been made to correct them.

Also note that Petrie's comments which originally appeared in the margins or at the bottom of the page have been edited to appear closer to the text in question, that is to say immediately following it. In webpage format you also have the advantage of being able to click on a reference link, namely the illustration plates that Petrie included at the back of his book.

Petrie's 1880-1883 measurements for the Great pyramid are not the only ones available but they are the most reliable. Almost all serious investigations now quote Petrie. Sometimes the Egyptian government survey of 1925 is also quoted, as is the Cole survey of the same year. In the notes, where necessary, I have included the 1925 government measures for comparison.

I cannot vouch that the text and tables of the original book have been faithfully reproduced in these pages. Errors will always occur and go unnoticed for a time. The longer the book stays online the more chance there is of spotting something, so if some part or other seems strange in the reading or you find what appears to be an anomaly please send mail.

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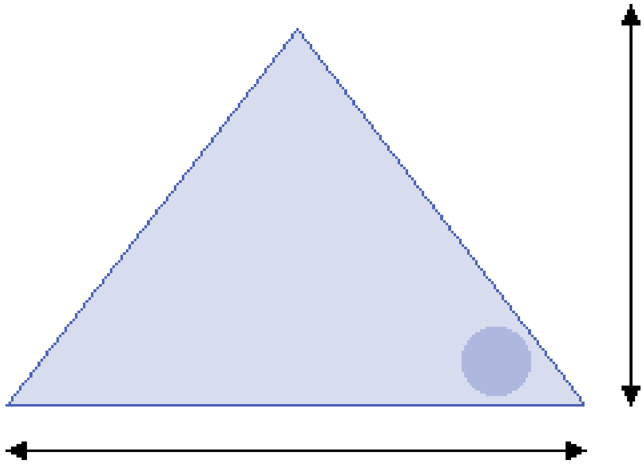


THE GREAT PYRAMID
outer measures

Base	9068.8 ± .5 inches = **755.69 - 755.78 ft.** (Egyptian Govt survey, 1925. **755.44 - 756.08 ft)** #	ref 1 ref 2
Height	**5776.0 ± 7.0 inches = 480.75 - 481.92 ft.** (Egyptian Govt survey, 1925. **481.4 ft**)	ref.
Seke slope	51° 52' ± 2' observations with goniometer 51° 48' - 51° 57', Casing stones "in situ", approx 51° 45' - 51° 49' ## (Egyptian Govt survey. 1925. 51° 52')	ref. ref.

Square base seen as uneven. (Egyptian Govt survey, 1925). It might have been measured that way in 1925 but if we listen to Petrie who praises Khufu's "quality of workmanship", it is most unlikely that the square base on the pavement would have originally been finished as anything but true.

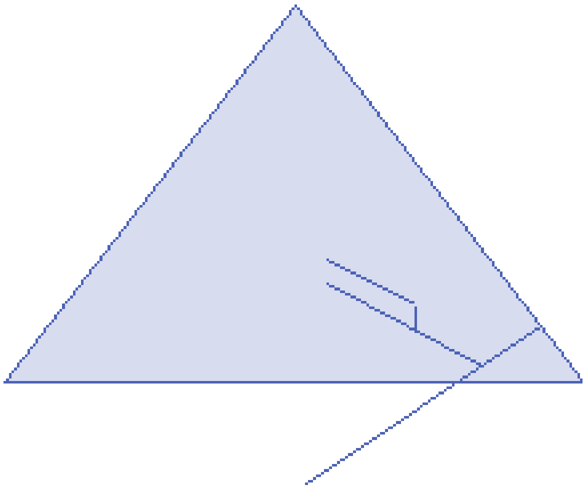
If Petrie slightly misread the true baseline or the true baseline level, as has often been suggested, then it is quite possible that the lesser angles offer a better estimate for the original slope; ie :
Casing stones in situ 51° 45' - 51° 49' (theodolite)

Note : The Great Pyramid has been in ruins for a very long time. When its outer casing fell to the ground all hope of recording its true dimensions ceased there and then. We really do not know its true baseline, hence its height and slope. At some time or other the pyramid was also hit by natural disasters (Petrie). A series of earthquakes would not seem an unreasonable assumption so our best estimates will now probably rely on the ability of future researchers to declare it a true geometric structure, one that responds to known proportions.

Related information :

Khufu, the Trial Site

Next page
Inside the Pyramid
Passageways angles



THE GREAT PYRAMID
inner measures

Descending passage	26º 31' 23" ± 5" ?	ref.
Ascending passage	Lower part (up to Gallery) 26º 02' 30"	ref.
	Upper part (Gallery) 26º 16' 40"	ref.
	Mean of whole 26º 12' 50"	ref.

With the ascending passage, we may well ask why the masons worked their way up to the beginning of the Gallery at approximately 26º 02' but then changed it noticeably for the Gallery itself. Did the masons stop at the Gallery to re-calculate after some concern was raised about the angle of the newly laid floor ?. Would it have missed its mark at King's chamber height ?. Perhaps the angle of the Gallery floor was then readjusted to bring it back in line with the planned angle. Petrie's data "Mean of whole" 26º 12' 50" may in fact reflect the planned angle closer than we think. This being the case we still have two different angles to contend with, the ascending about a 1/3 of a degree less than the descending. The question is ... why were the two angle planned this way and what was behind their geometry ? Of course if the descending passageway wasn't honed with incredible accuracy (a consistent altitude) we might not be asking these questions.

True scale : If drawing the Great pyramid to scale Section 64 is to be consulted for it has all the necessary measurement to correctly place the passageways and chambers.

Metrology

Royal cubit (base of King's chamber) **20.632 ± .004 inches** (523.95 - 524.15mm)	ref.
Royal cubit (summary King's chamber) **20.620 ± .005 inches** (523.62 - 523.87mm)	ref.
Digit (unit named by Petrie) ... **.727 ± .002 inches** (18.41 - 18.52mm)	ref.

Note : The royal cubit standard agreed upon for the 4th dynasty is generally quoted as the second measure, ie; **20.620 ± .005 inches** although as you can see there is but 1/3rd of a millimetre difference between them. The digit, so named by Petrie, is mainly from the 4th dynasty tombs he examined and it is consistently accurate to within 1/10th of a millimetre. It is by far the best indication we have for metrological proficiency during this period.

THE
PYRAMIDS AND TEMPLES
OF GIZEH.

BY

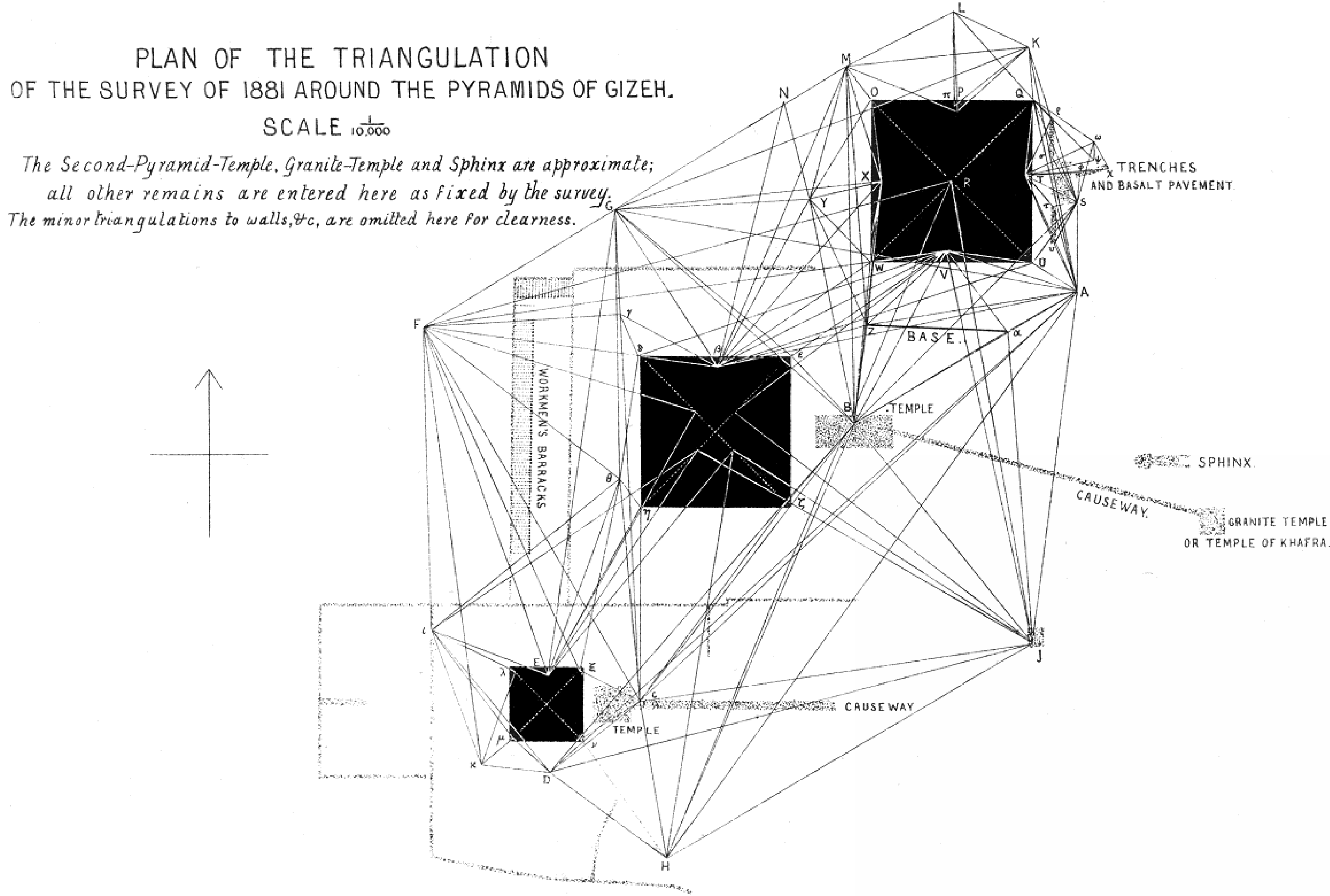
SIR W.F.M. FLINDERS PETRIE

Author of "Inductive Metrology," "Stonehenge," &c,

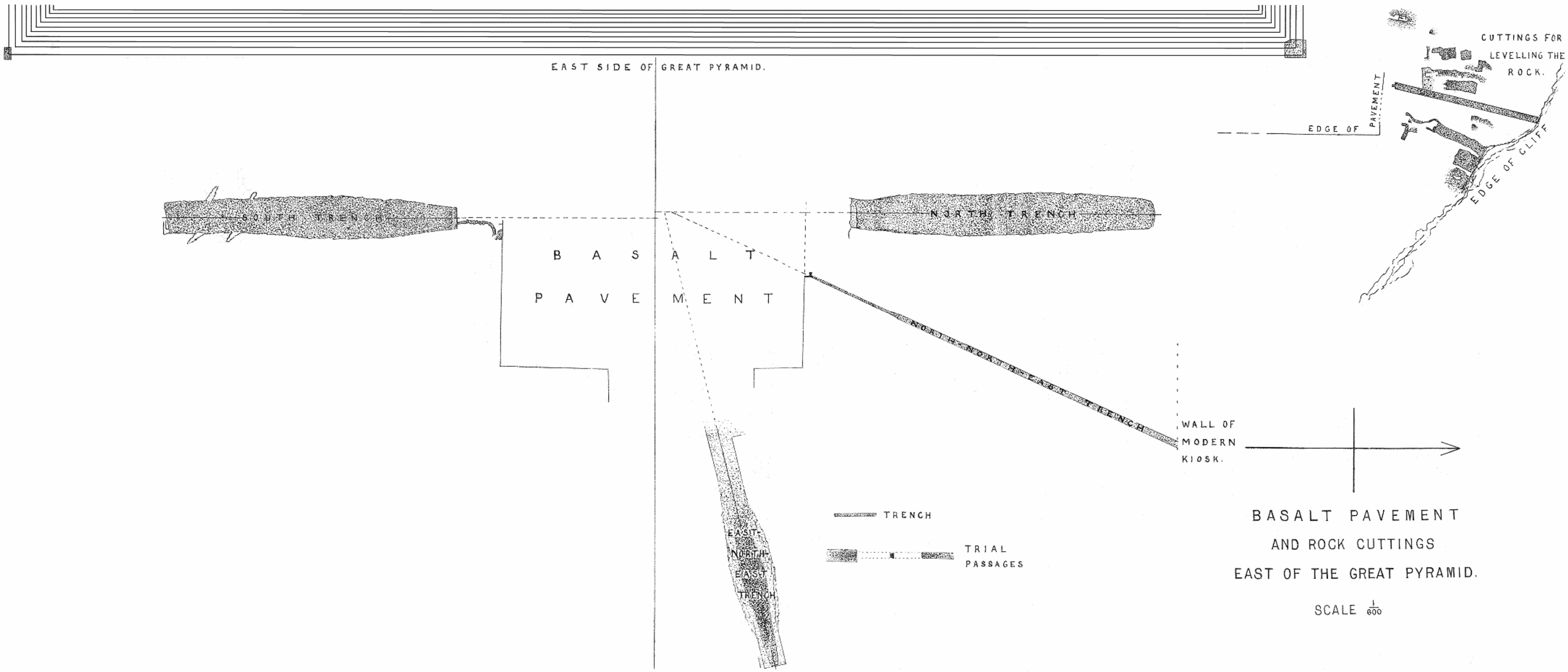
1883

LONDON;
FIELD & TUER, YE LEADENHALLE PRESSE; SIMPKIN, MARSHALL & CO., STATIONERS' HALL COURT; HAMILTON, ADAMS & CO., PATERNOSTER ROW.
NEW YORK: SCRIBNER & WELFORD, 743, BROADWAY.

PUBLISHED WITH THE ASSISTANCE OF A VOTE OF ONE HUNDRED POUNDS FROM THE GOVERNMENT-GRANT COMMITTEE OF THE ROYAL SOCIETY, 1883


PLAN OF THE TRIANGULATION
OF THE SURVEY OF 1881 AROUND THE PYRAMIDS OF GIZEH.
SCALE $\frac{1}{10,000}$
The Second-Pyramid-Temple, Granite-Temple and Sphinx are approximate;
all other remains are entered here as fixed by the survey.
The minor triangulations to walls, &c, are omitted here for clearness.
TRENCHES
AND BASALT PAVEMENT
BASE.
TEMPLE
SPHINX.
CAUSEWAY.
GRANITE TEMPLE
OR TEMPLE OF KHAFRA.
WORKMEN'S BARRACKS
CAUSEWAY
TEMPLE

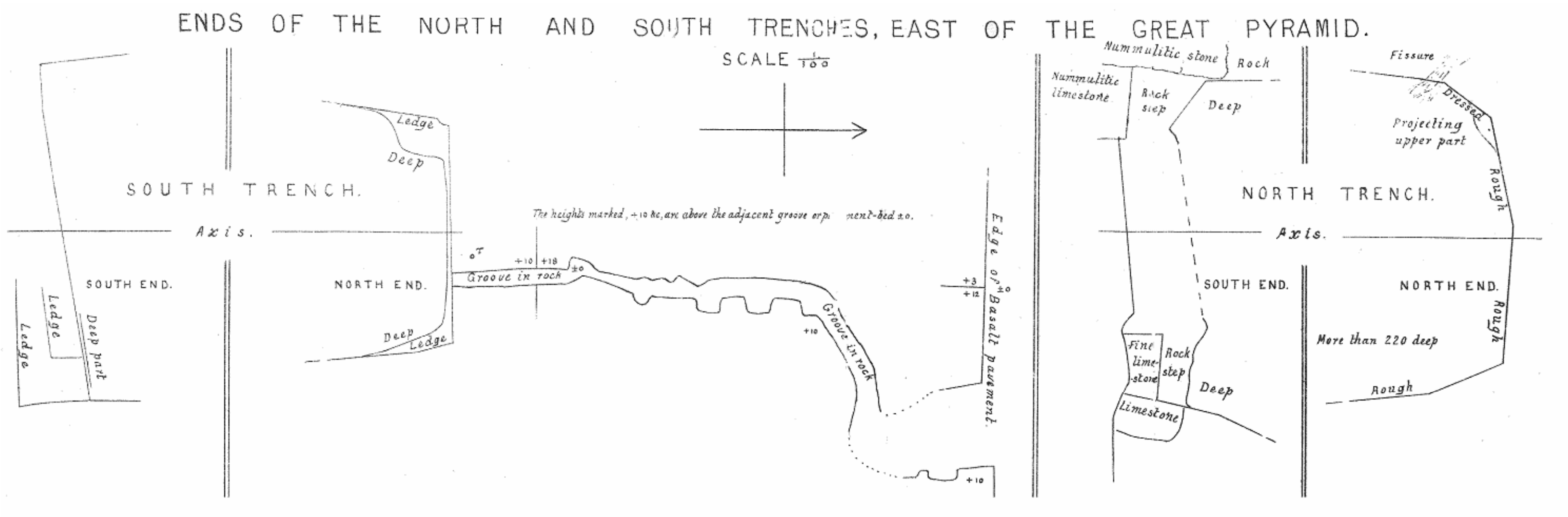
scanned image approx twice the size of the original

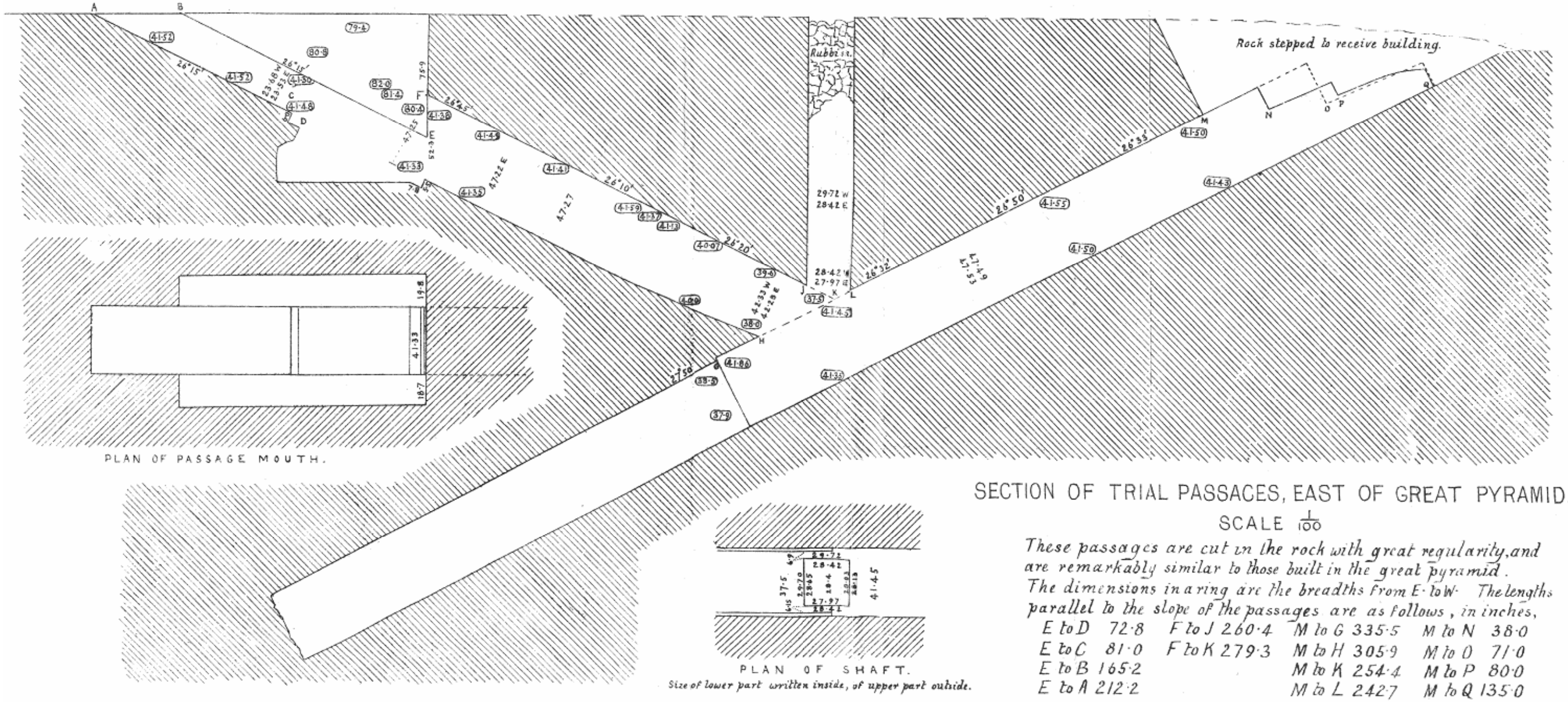


BASALT PAVEMENT
AND ROCK CUTTINGS
EAST OF THE GREAT PYRAMID.

SCALE $\frac{1}{600}$

Thos Bell & Son, Photo-Lith. 46, King St. Covent Garden.


ENDS OF THE NORTH AND SOUTH TRENCHES, EAST OF THE GREAT PYRAMID.
SCALE 1/100
SOUTH TRENCH.
Axis.
SOUTH END.
NORTH END.
Ledge
Deep
Deep part
The heights marked, +10 &c, are above the adjacent groove or pavement-bed ±0.
Groove in rock
+10
+18
±0
+3
+12
Edge of Basalt pavement.
+10
NORTH TRENCH.
Nummulitic stone
Rock
Nummulitic limestone
Rock step
Fine limestone
Limestone
Fissure
Dressed
Projecting upper part
Rough
More than 220 deep

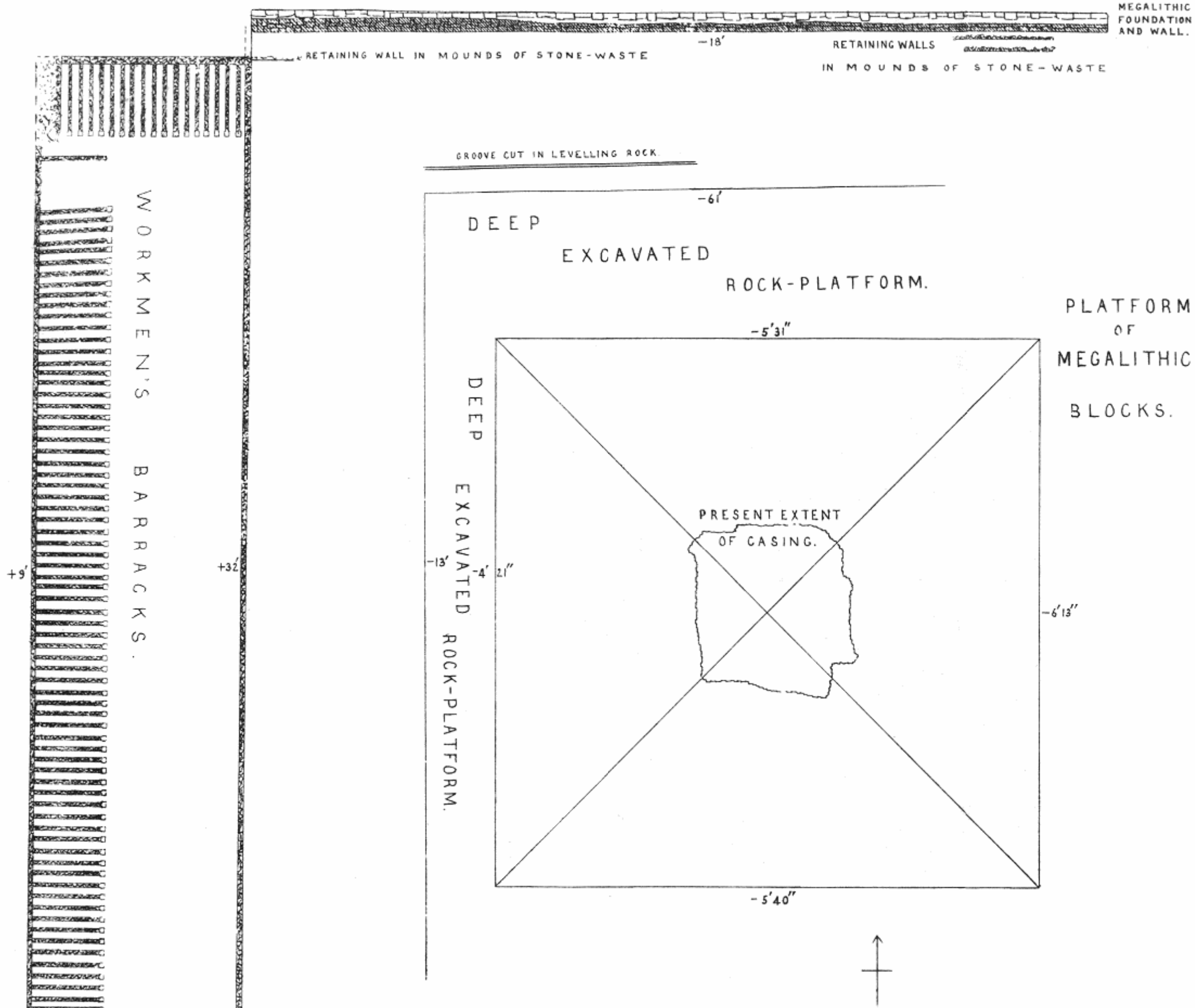


SECTION OF TRIAL PASSAGES, EAST OF GREAT PYRAMID.

SCALE $\frac{1}{100}$

These passages are cut in the rock with great regularity, and are remarkably similar to those built in the great pyramid. The dimensions in a ring are the breadths from E. to W. The lengths parallel to the slope of the passages are as follows, in inches,

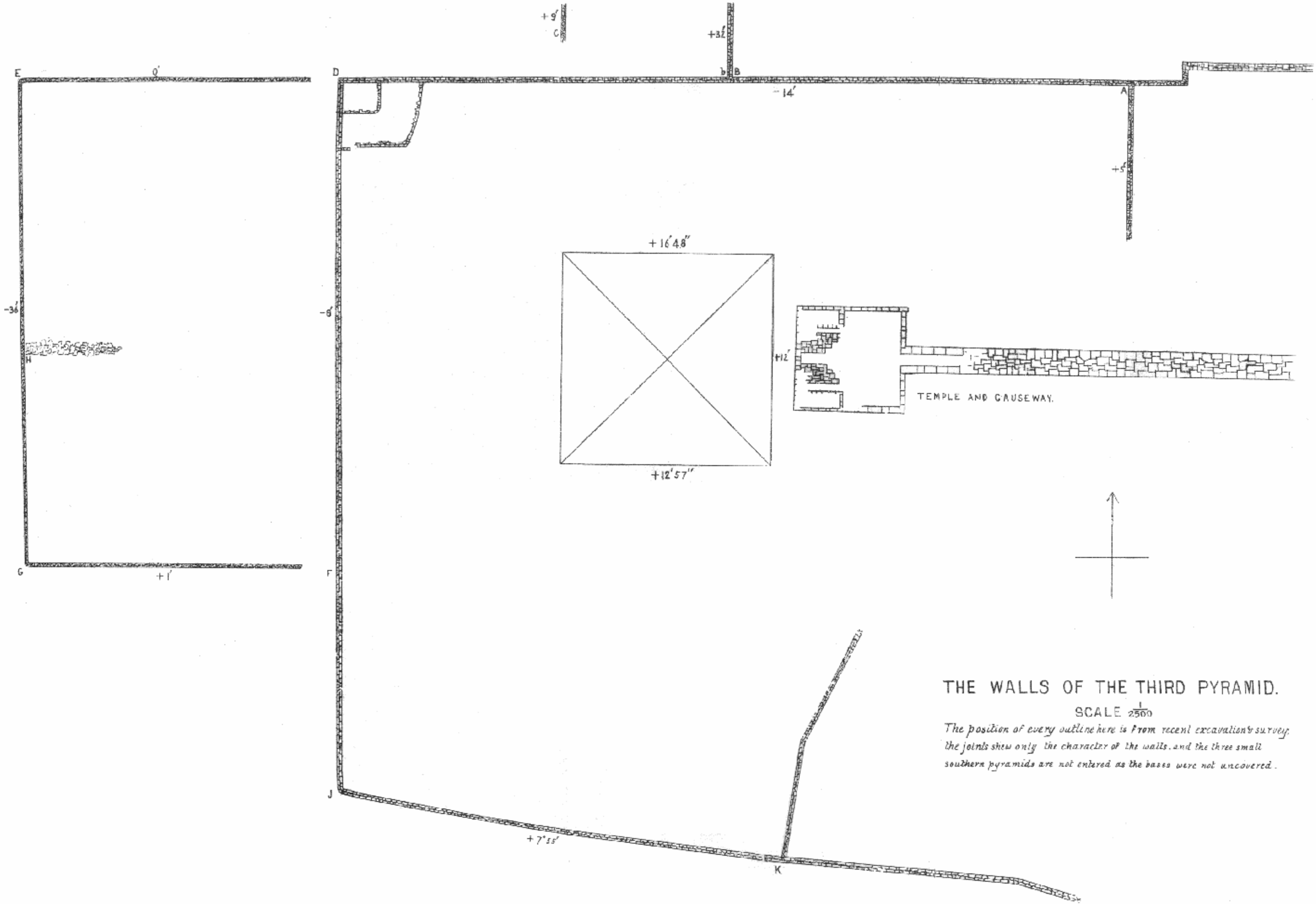
E to D 72·8	F to J 260·4	M to G 335·5	M to N 38·0
E to C 81·0	F to K 279·3	M to H 305·9	M to O 71·0
E to B 165·2		M to K 254·4	M to P 80·0
E to A 212·2		M to L 242·7	M to Q 135·0



WALLS AND BARRACKS AROUND THE SECOND PYRAMID.

SCALE $\frac{1}{2500}$

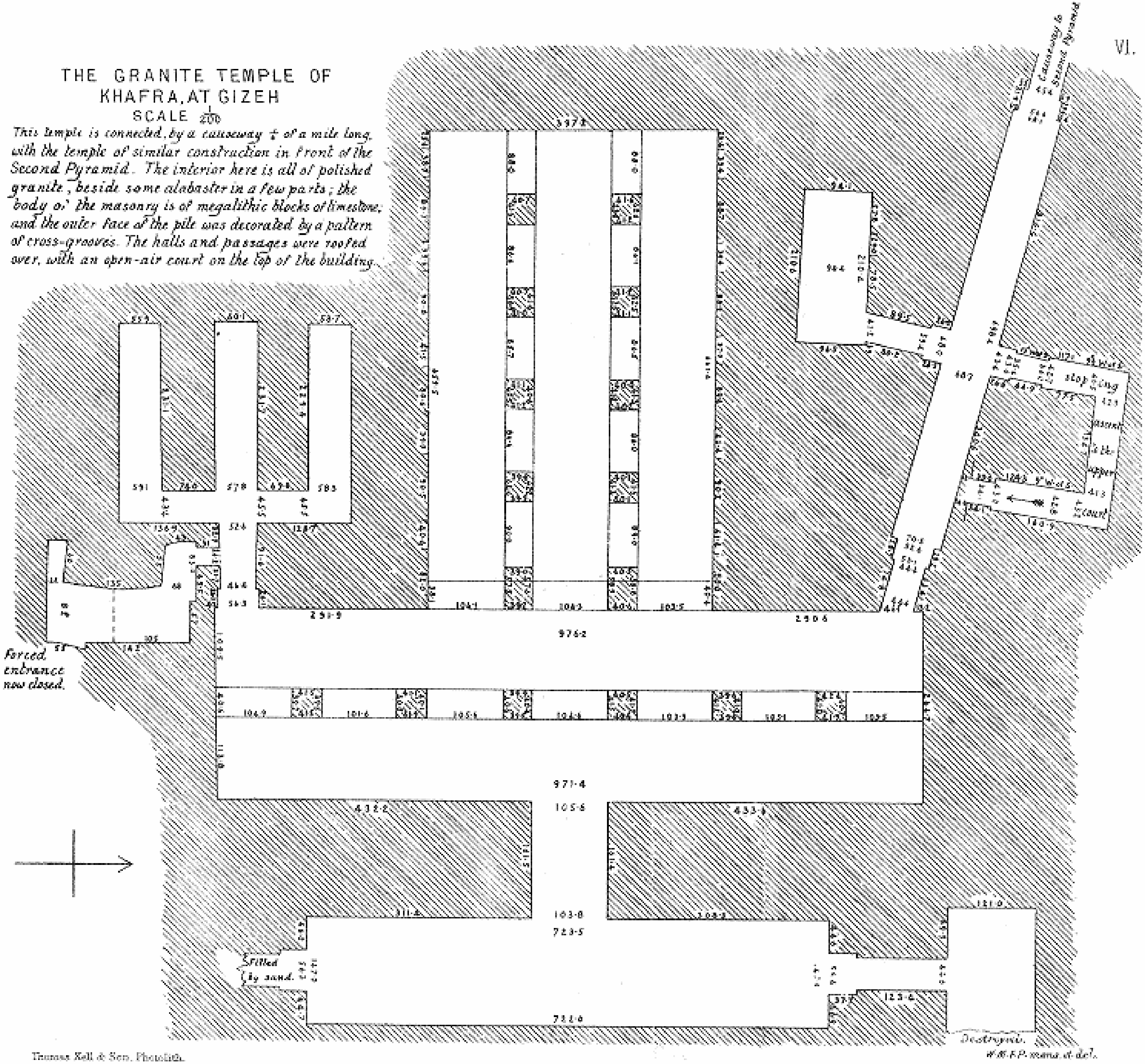
Each point here entered is fixed by recent excavations and survey; the corners of the cap of casing were triangulated, and the edge filled in from photographs.
The barracks are suitable for 3600 men; the Northern galleries were cleared in parts, and nearly all the wall-faces measured; the Western galleries were found uniform in each part cleared, and the middles of nearly all the walls measured.
The most perfect galleries are still about 7 feet high, each with fine stone terminal.


+9'
C
+32'
E
0'
D
b
B
-14'
A
+5'
+16'4.8"
-36'
-8'
H
+12'
TEMPLE AND CAUSEWAY.
+12'57"
G
+1'
F
J
+7°55'
K
THE WALLS OF THE THIRD PYRAMID.
SCALE 1/2500
The position of every outline here is from recent excavation & survey;
the joints shew only the character of the walls, and the three small
southern pyramids are not entered as the bases were not uncovered.

VI.

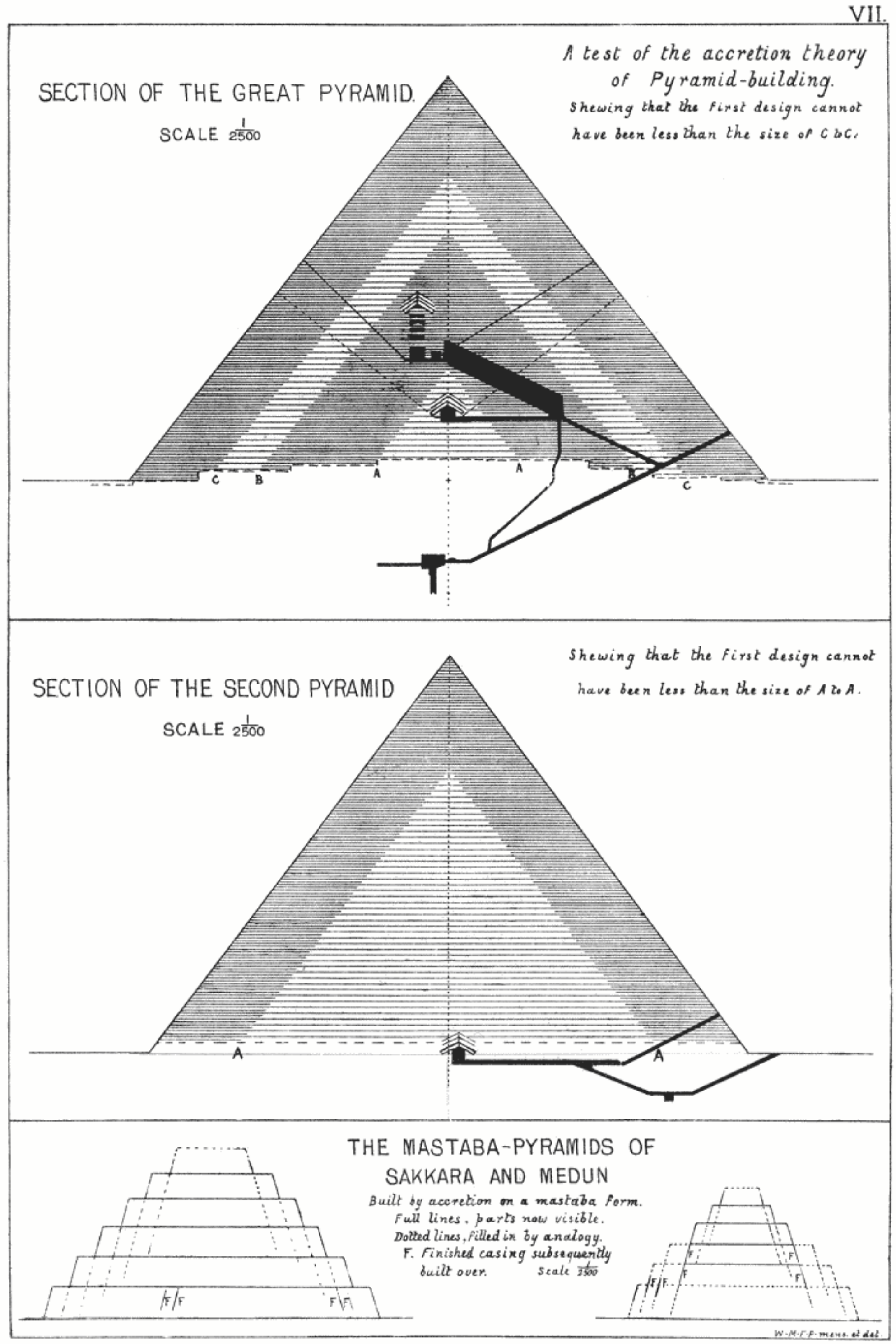
THE GRANITE TEMPLE OF
KHAFRA, AT GIZEH
SCALE $\frac{1}{200}$

This temple is connected, by a causeway ¼ of a mile long, with the temple of similar construction in front of the Second Pyramid. The interior here is all of polished granite, beside some alabaster in a few parts; the body of the masonry is of megalithic blocks of limestone; and the outer face of the pile was decorated by a pattern of cross-grooves. The halls and passages were roofed over, with an open-air court on the top of the building.



Thomas Kell & Son, Photolith.

W.M.F.P. mens. et del.

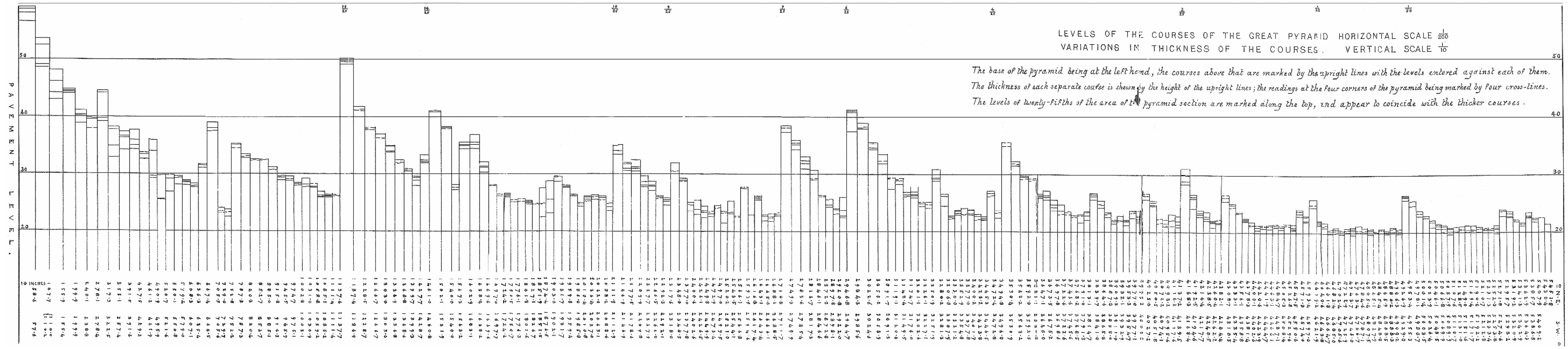


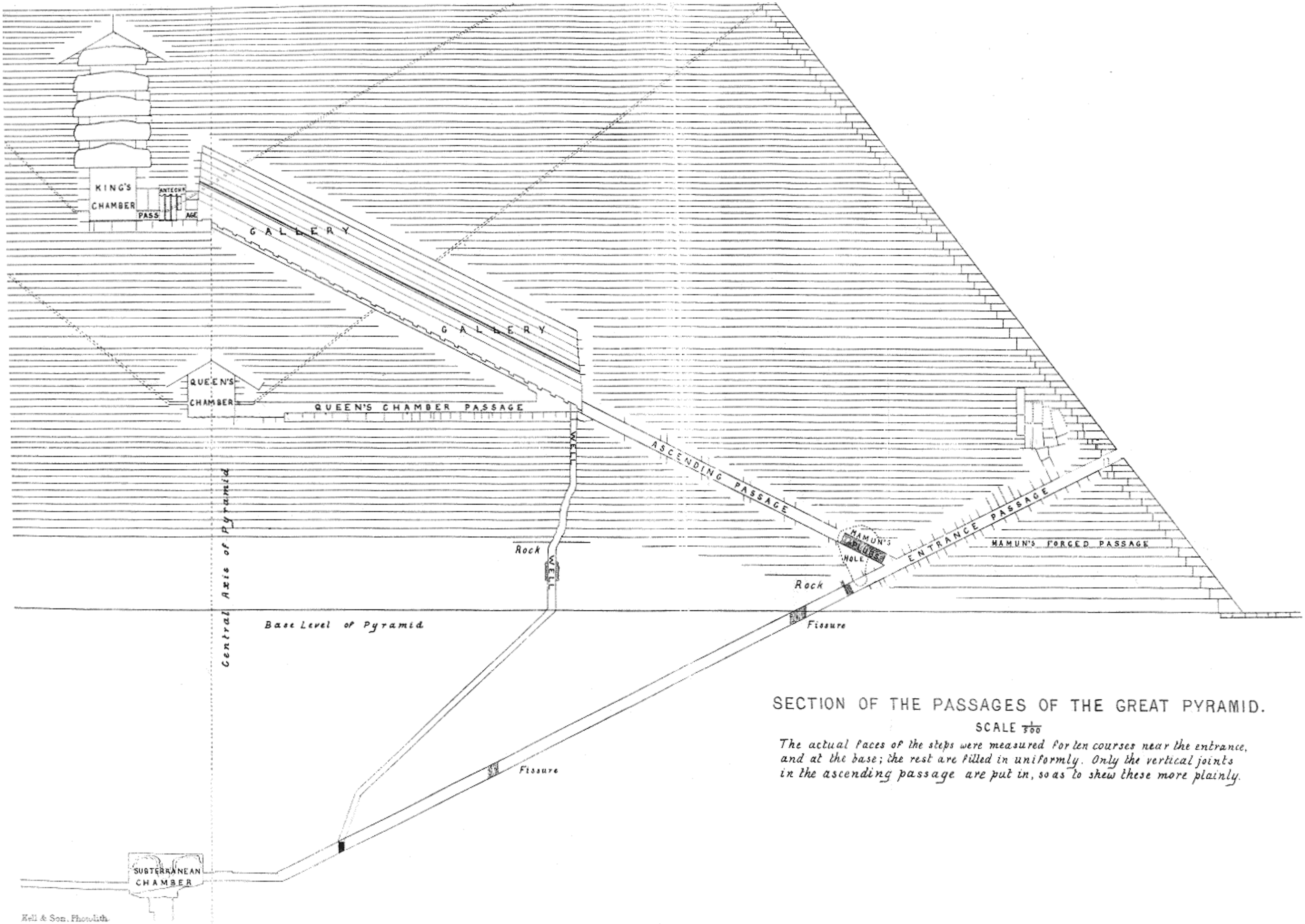
Thomas Kell & Son, Photolith.

Plate 8a.

Courses of the Great Pyramid

From Petrie's explanation (to the right) we gather that the thicker the course the higher it is represented, ie; the first and second courses are the thickest. Course thirty five comes next and then course three.
On an additional illustration **Plate 8b** I have re-entered the course data, numbered each course and added the relevant information for thickness.





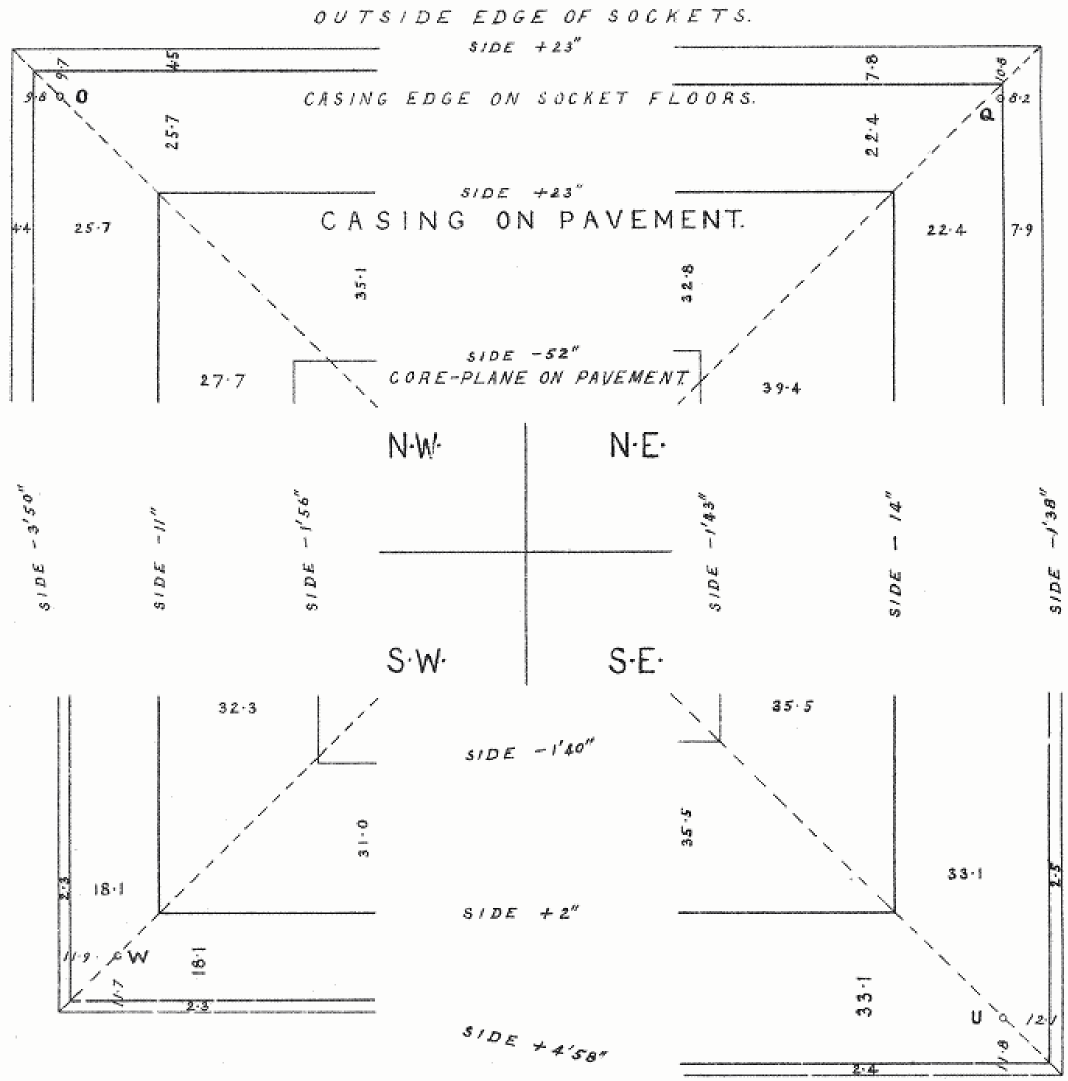
SECTION OF THE PASSAGES OF THE GREAT PYRAMID.

SCALE $\frac{1}{500}$

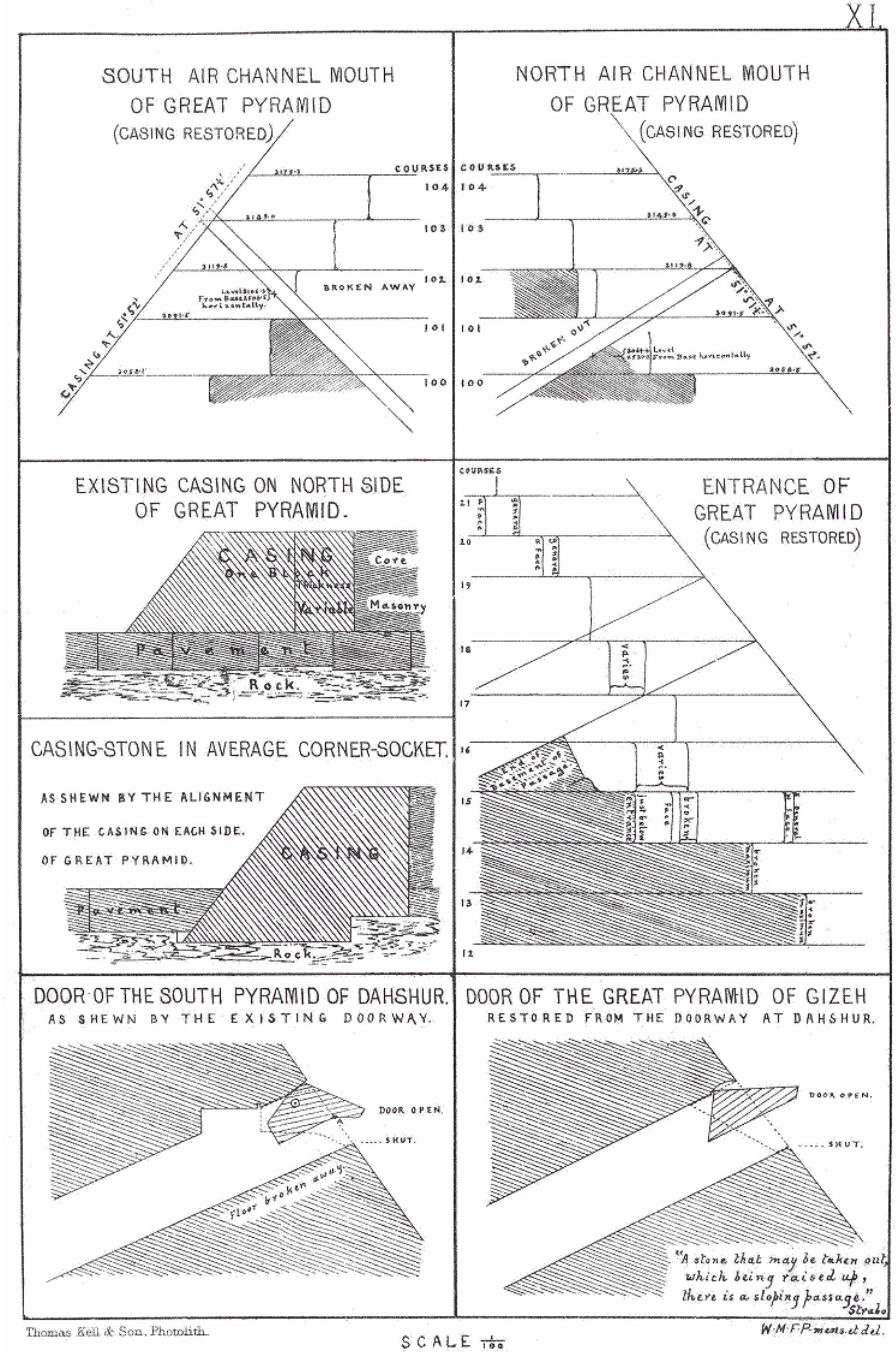
The actual faces of the steps were measured for ten courses near the entrance, and at the base; the rest are filled in uniformly. Only the vertical joints in the ascending passage are put in, so as to shew these more plainly.

THE RELATIVE POSITION OF THE SOCKET-EDGES, CASING, AND CORE-MASONRY, AT THE CORNERS OF THE GREAT PYRAMID

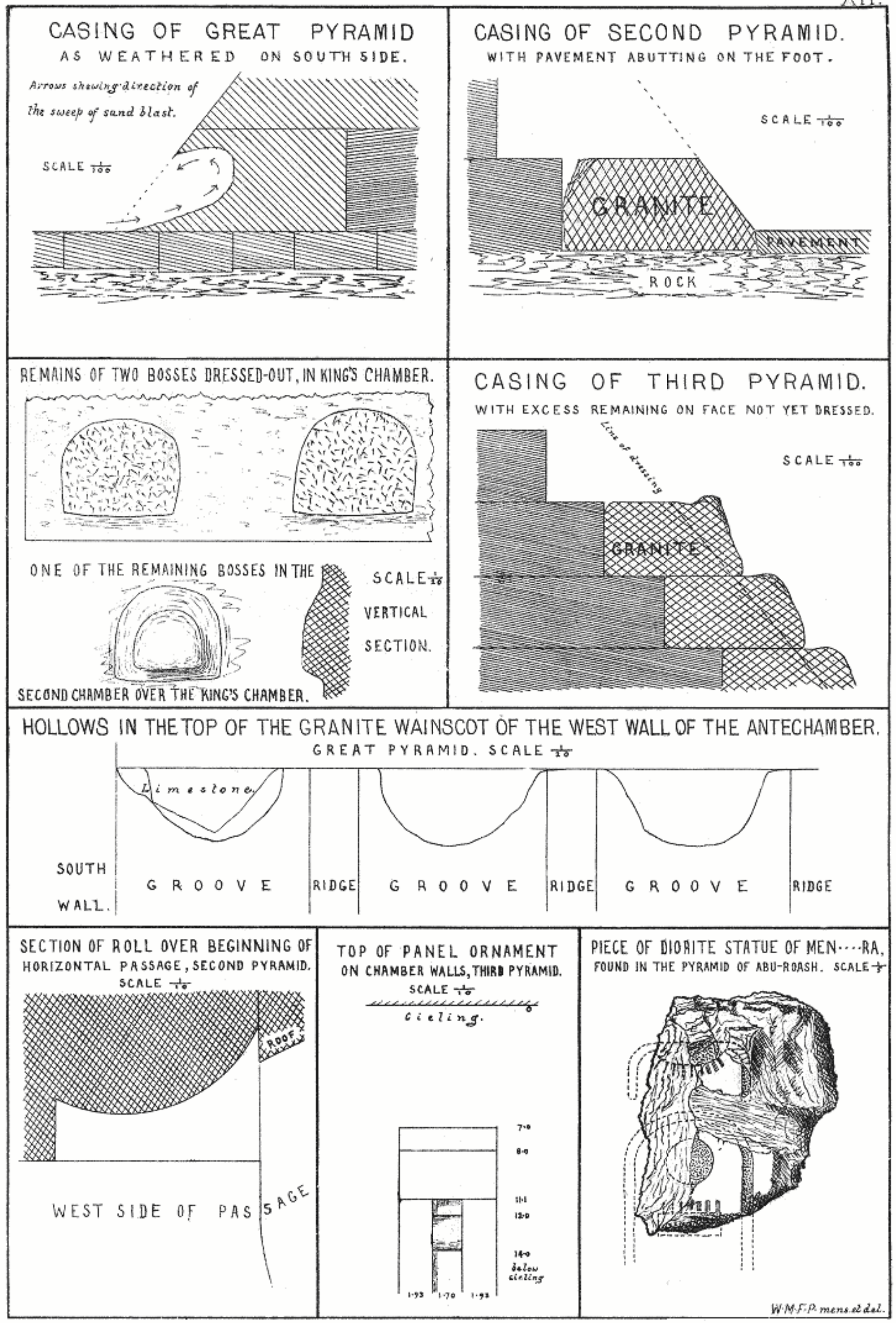
SCALE $\frac{1}{50}$



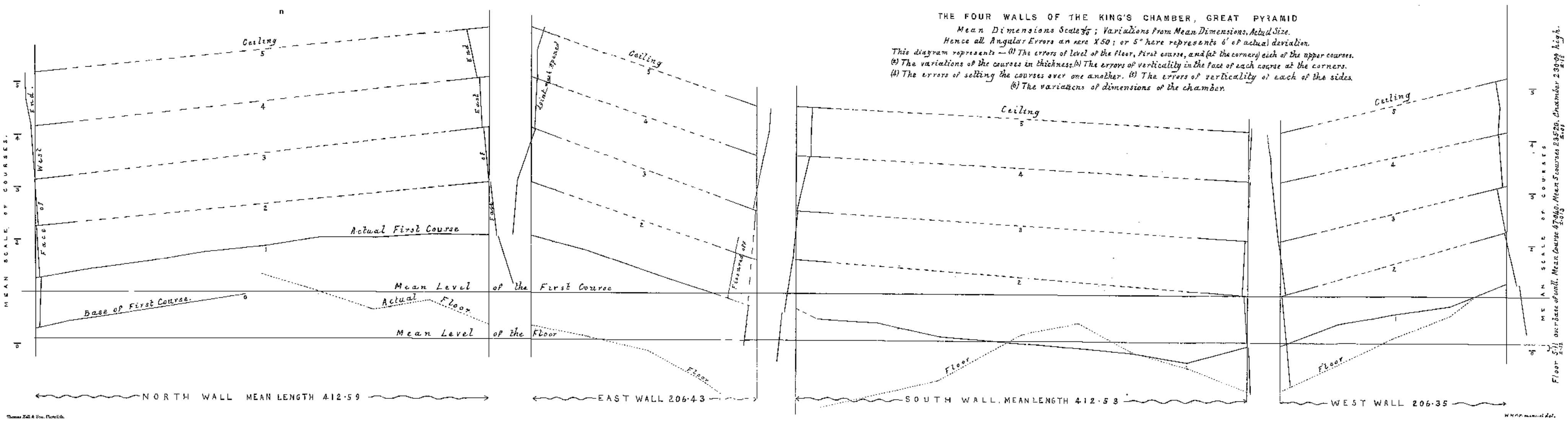
The azimuths of the sides stated are from the mean azimuth of the casing on pavement, which is −3′43″, i.e. W. of N.
The station-marks O. Q. U. and W. are marked in position.


XI.
SOUTH AIR CHANNEL MOUTH
OF GREAT PYRAMID
(CASING RESTORED)
CASING AT 51° 52'
AT 51° 57½'
COURSES
104
103
102
101
100
BROKEN AWAY
NORTH AIR CHANNEL MOUTH
OF GREAT PYRAMID
(CASING RESTORED)
CASING AT 51° 57½'
AT 51° 52'
BROKEN OUT
EXISTING CASING ON NORTH SIDE
OF GREAT PYRAMID.
CASING
One Block
Thickness
Variable
Core
Masonry
Pavement
Rock.
CASING-STONE IN AVERAGE CORNER-SOCKET.
AS SHEWN BY THE ALIGNMENT
OF THE CASING ON EACH SIDE.
OF GREAT PYRAMID.
CASING
Pavement
Rock.
ENTRANCE OF
GREAT PYRAMID
(CASING RESTORED)
End of Basement Passage
varies
broken
DOOR OF THE SOUTH PYRAMID OF DAHSHUR.
AS SHEWN BY THE EXISTING DOORWAY.
DOOR OPEN.
SHUT.
Floor broken away.
DOOR OF THE GREAT PYRAMID OF GIZEH
RESTORED FROM THE DOORWAY AT DAHSHUR.
DOOR OPEN.
SHUT.
"A stone that may be taken out, which being raised up, there is a sloping passage." Strabo
Thomas Kell & Son, Photolith.
SCALE 1/100
W.M.F.P. mens. et del.

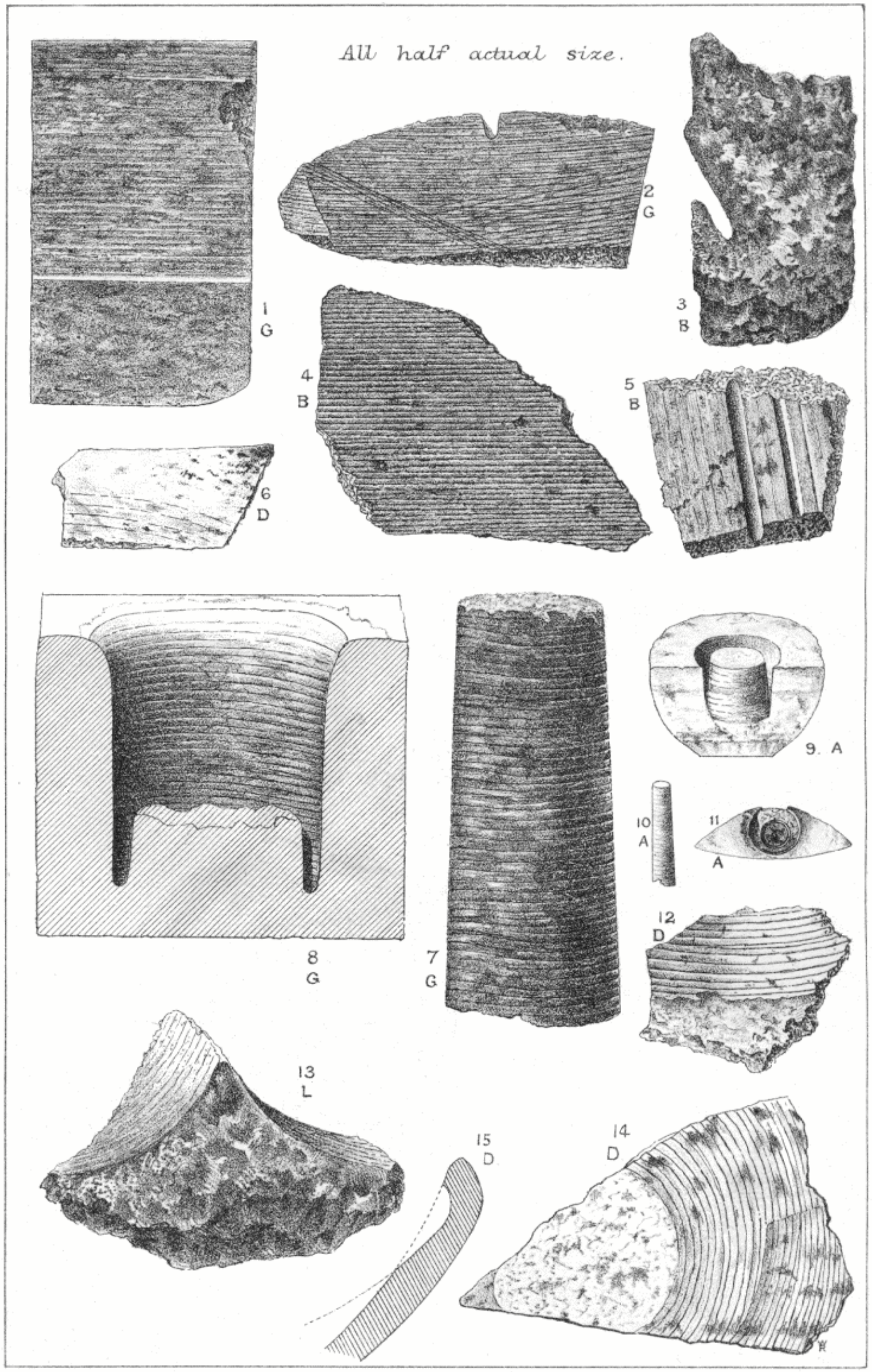
XII.



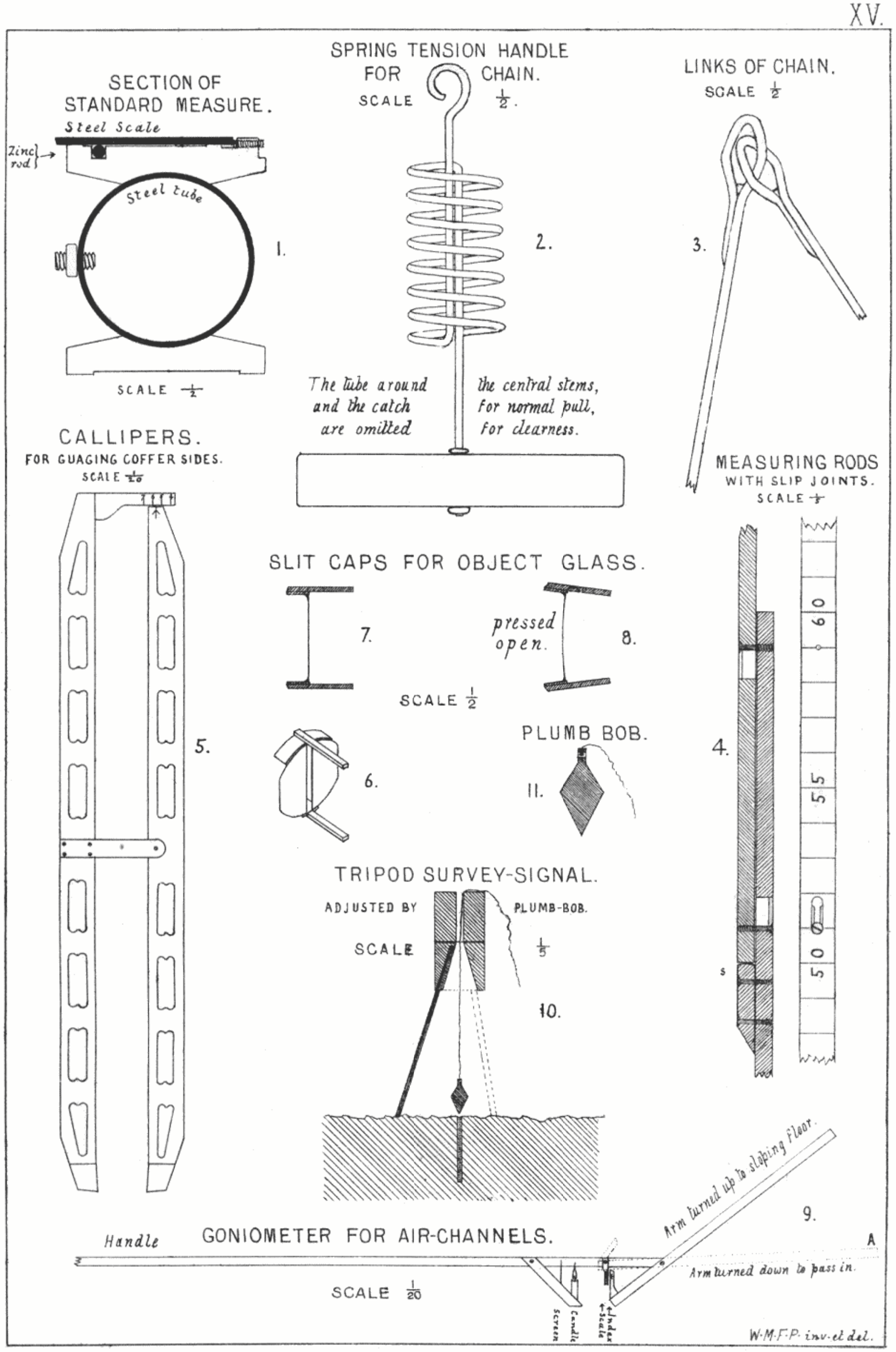
Thomas Kell & Son, Photolith.


THE FOUR WALLS OF THE KING'S CHAMBER, GREAT PYRAMID
Mean Dimensions Scale 1/50 ; Variations from Mean Dimensions, Actual Size.
Hence all Angular Errors are here X50 ; or 5° here represents 6' of actual deviation.
This diagram represents — (1) The errors of level of the floor, first course, and (at the corners) each of the upper courses.
(2) The variations of the courses in thickness. (3) The errors of verticality in the face of each course at the corners.
(4) The errors of setting the courses over one another. (5) The errors of verticality of each of the sides.
(6) The variations of dimensions of the chamber.
Ceiling
Actual First Course
Mean Level of the First Course
Base of First Course.
Actual Floor
Mean Level of the Floor
Face of West End
East End
Floor
NORTH WALL MEAN LENGTH 412·59
EAST WALL 206·43
SOUTH WALL. MEAN LENGTH 412·53
WEST WALL 206·35
MEAN SCALE OF COURSES.

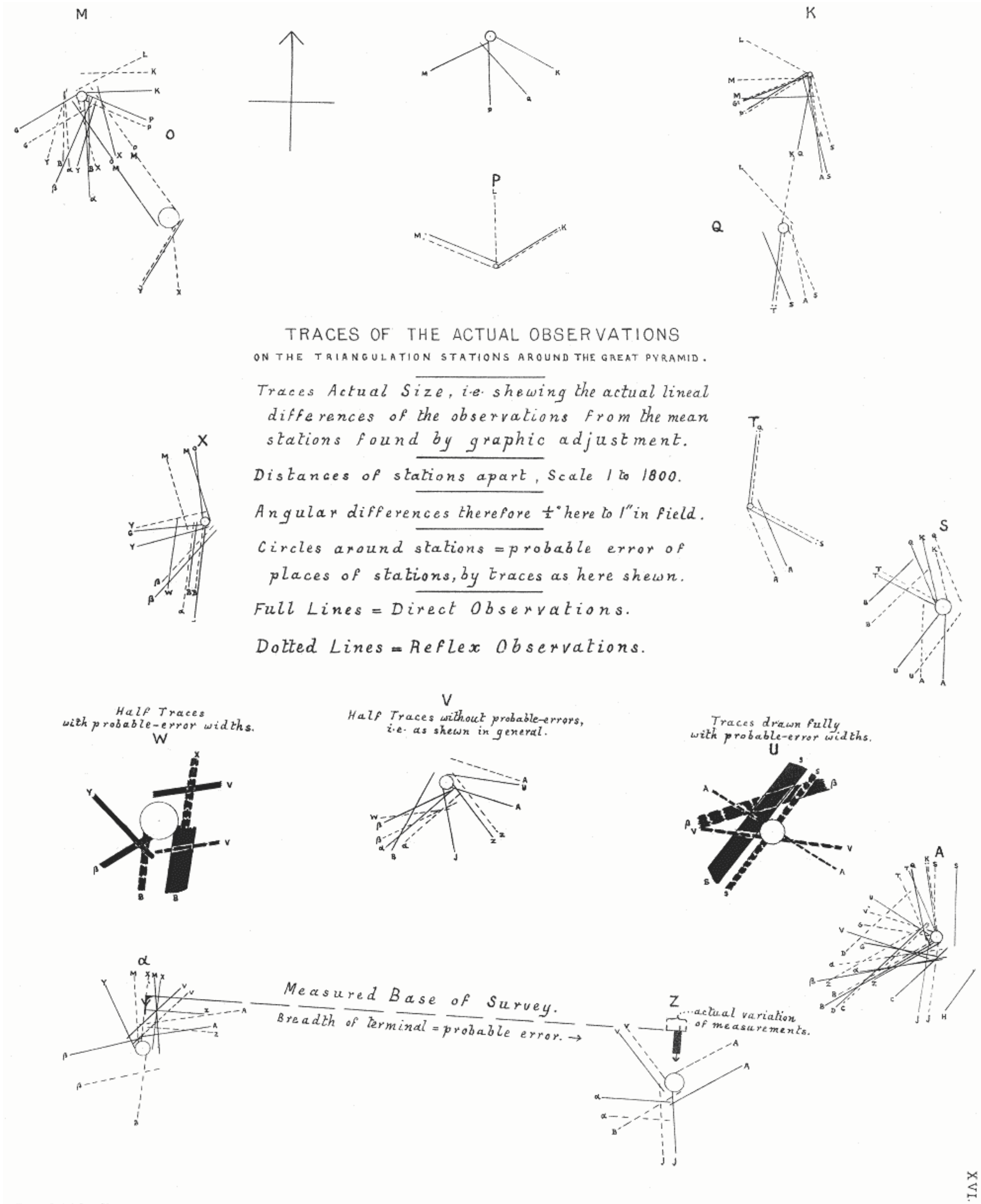
EARLY EGYPTIAN STONE CUTTING. XIV.



A. *Alabaster.* B. *Basalt.* D. *Diorite.* G. *Granite.* L. *Limestone.*



Thomas Kell & Son, Photolith.


TRACES OF THE ACTUAL OBSERVATIONS
ON THE TRIANGULATION STATIONS AROUND THE GREAT PYRAMID.
Traces Actual Size, i.e. shewing the actual lineal differences of the observations from the mean stations found by graphic adjustment.
Distances of stations apart, Scale 1 to 1800.
Angular differences therefore $\frac{1}{4}$° here to 1″ in field.
Circles around stations = probable error of places of stations, by traces as here shewn.
Full Lines = Direct Observations.
Dotted Lines = Reflex Observations.
Half Traces with probable-error widths.
Half Traces without probable-errors, i.e. as shewn in general.
Traces drawn fully with probable-error widths.
Measured Base of Survey.
Breadth of terminal = probable error. →
actual variation of measurements.
M
K
P
Q
O
X
T
S
W
V
U
A
α
Z
XVI.
Thomas Kell & Son, Photolith.

COURSE DATA and SITE COMMENTARY

Starting from the top of the pyramid and working down to the base (after Petrie). Two entries given for the progressive **top** of each course, ie; from the N.E. and S.W. corners above base. I have added the thicknesses for each course and the difference between the N.E. and S.W. readings, both in thickness and in level. There is also a column illustrating the **approximate** variation between the 4 corner thicknesses, corresponding to the 4 horizontal thickness bars on the previous illustration (**plate 8a**).

N.E. level	thickness	S.W. level	thickness	variation level	variation thickness	variation in thickness 4 corners	course
5451.8	21.4	-	--	--	--	--	203
5430.4	22.5	-	--	--	--	--	202
5407.9	22.2	5409.2	22.4	1.3	0.2	0.5	201
5385.7	22.8	5386.8	22.5	1.1	0.3	0.9	200
5362.9	21.6	5364.3	21.4	1.4	0.2	0.5	199
5341.3	22.1	5342.9	22.0	1.6	0.1	0.3	198
5319.2	23.5	5320.9	22.7	1.7	0.8	1.0	197
5295.7	23.9	5298.2	23.6	2.5	0.3	1.1	196
5271.8	19.8	5274.6	20.8	2.8	1.0	1.2	195
5252.0	20.7	5253.8	20.4	1.8	0.3	0.5	194
5231.3	20.6	5233.4	20.6	2.1	0	0.2	193
5210.7	20.1	5212.8	20.6	2.1	0.5	0.9	192
5190.6	21.2	5192.2	20.5	1.6	0.7	0.9	191
5169.4	20.4	5171.7	20.1	2.3	0.3	1.0	190
5149.0	20.5	5151.6	20.6	2.6	0.1	0.6	189
5128.5	20.9	5131.0	20.3	2.5	0.6	0.9	188
5107.6	19.7	5110.7	20.8	3.1	1.1	1.1	187
5087.9	21.1	5089.9	20.0	2.0	1.1	1.2	186
5066.8	20.7	5069.9	21.4	3.1	0.7	0.8	185
5046.1	22.2	5048.5	22.1	2.4	0.1	1.2	184
5023.9	22.5	5026.4	22.9	2.5	0.4	0.5	183
5001.4	23.3	5003.5	22.8	2.1	0.5	1.0	182
4978.1	24.7	4980.7	25.4	2.6	0.7	1.0	181
N.E. level	**thickness**	**S.W. level**	**thickness**	**variation level**	**variation thickness**	**variation in thickness 4 corners**	**course**
4953.4	26.5	4955.3	26.3	1.9	0.2	0.9	180
4926.9	20.6	4929.0	19.8	2.1	0.8	0.9	179
4906.3	20.1	4909.2	20.9	2.9	0.8	0.8	178
4886.2	20.3	4888.3	19.8	2.1	0.5	0.6	177
4865.9	20.5	4868.5	20.5	2.6	0	0.2	176
4845.4	20.3	4848.0	20.1	2.6	0.2	0.2	175
4825.1	19.7	4827.9	20.4	2.8	0.7	0.7	174
4805.4	20.8	4807.5	20.4	2.1	0.4	0.6	173
4784.6	21.2	4787.1	20.4	2.5	0.8	1.0	172
4763.4	19.7	4766.7	20.7	3.3	1.0	1.0	171
4743.7	20.8	4746.0	20.1	2.3	0.7	0.8	170
4722.9	20.5	4725.9	20.3	3.0	0.2	0.6	169
4702.4	20.0	4705.6	20.6	3.2	0.6	0.9	168
4682.4	20.6	4685.0	20.3	2.6	0.3	0.7	167
4661.8	21.2	4664.7	20.9	2.9	0.3	1.0	166
4640.6	21.4	4643.8	21.9	3.2	0.5	0.5	165
4619.2	25.8	4621.9	24.9	2.7	0,9	1.4	164
4593.4	22.1	4597.0	23.0	3.6	0.9	1.0	163
4571.3	23.8	4574.0	23.4	2.7	0.4	1.2	162
4547.5	20.7	4550.6	21.0	3.1	0.3	0.9	161
4526.8	21.5	4529.6	21.2	2.8	0.3	0.3	160
4505.3	20.6	4508.4	21.3	3.1	0.7	0.7	159
4484.7	21.6	4487.1	21.0	2.4	0.6	0.6	158
4463.1	21.2	4466.1	21.4	3.0	0.2	0.7	157
4441.9	21.3	4444.7	20.8	2.8	0.5	0.6	156
4420.6	20.5	4423.9	21.3	3.3	0.8	0.8	155
4400.1	21.8	4402.6	21.2	2.5	0.6	0.7	154
4378.3	22.2	4381.4	22.6	3.1	0.4	0.8	153
4356.1	23.0	4358.8	23.4	2.7	0.4	0.5	152
4333.1	24.4	4335.4	24.9	2.3	0.5	0.6	151

N.E. level	thickness	S.W. level	thickness	variation level	variation thickness	variation in thickness 4 corners	course
4308.7	26.6	4310.5	26.1	1.8	0.5	1.2	150
4282.1	21.7	4284.4	22.2	2.3	0.5	0.8	149
4260.4	21.9	4262.2	21.7	1.8	0.2	1.7	148
4238.5	22.1	4240.5	22.8	2.0	0.7	1.5	147
4216.4	23.9	4217.7	23.1	1.3	0.8	1.2	146
4192.5	24.2	4194.6	26.2	2.1	2.0	2.4	145
4168.3	31.1	4168.4	28.9	0.1	2.2	2.2	144
4137.2	20.9	4139,5	21.9	2.3	1.0	1.8	143
4116.3	23.1	4117.6	22.0	1.3	1.1	2.0	142
4093.2	21.0	4095.6	21.5	2.4	0.5	1.2	141
4072.2	21.7	4074.1	22.3	1.9	0.6	0.9	140
4050.5	25.5	4051.8	24.6	1.3	0.9	0.9	139
4025.0	25.7	4027.2	26.4	2.2	0.7	1.1	138
3999.3	22.3	4000.8	23.7	1.5	1.4	2.0	137
3977.0	23.7	3977.1	22.4	0.1	1.3	1.3	136
3953.3	21.2	3954.7	21.8	1.4	0.6	1.0	135
3932.1	22.8	3932.9	21.9	0.8	0,9	0.9	134
3909.3	21.5	3911.0	22.1	1.7	0.6	0.7	133
3887.8	23.2	3888.9	23.1	1.1	0.1	0.9	132
3864.6	24.9	3865.8	24.8	1.2	0.1	1.2	131
3839.7	26.6	3841.0	26.3	1.3	0.3	1.1	130
3813.1	22.1	3814.7	23.4	1.6	1.3	1.4	129
3791.0	22.8	3791.3	22.8	0.3	0	1.5	128
3768.2	22.6	3768.5	22.9	0.3	0.3	0.4	127
3745.6	23.0	3745.6	23.0	0	0	0.5	126
3722.6	24.8	3722.6	24.0	0	0.8	1.8	125
3697.8	24.3	3698.6	23.4	0.8	0.9	1.9	124
3673.5	26.4	3675.2	27.2	1.7	0.8	1.6	123
3647.1	26.0	3648.0	26.7	0.9	0.7	0.8	122
3621.1	29.1	3621.3	28.8	0.2	0.3	0.4	121
N.E. level	**thickness**	**S.W. level**	**thickness**	**variation level**	**variation thickness**	**variation in thickness 4 corners**	**course**
3592.0	29.8	3592.5	29.3	0.5	0.5	0.9	120
3562.2	31.8	3563.2	32.3	1.0	0.5	0.8	119
3530.4	35.6	3530.9	34.9	0.5	0.7	0.7	118
3494.8	22.4	3496.0	23.2	1.2	0.8	1.4	117
3472.4	27.1	3472.8	26.3	0.4	0.8	1.0	116
3445.3	22.1	3446.5	22.7	1.2	0.6	0.8	115
3423.2	23.0	3423.8	22.1	0.6	0.9	1.0	114
3400.2	23.2	3401.7	23.9	1.5	0.7	1.0	113
3377.0	24.1	3377.8	23.0	0.8	1.1	1.1	112
3352.9	22.9	3354.8	23.6	1.9	0.7	1.0	111
3330.0	23.2	3331.2	23.3	1.2	0.1	0.6	110
3306.8	26.6	3307.9	26.6	1.1	0	2.0	109
3280.2	29.3	3281.3	29.4	1.1	0.1	2.0	108
3250.9	24.8	3251.9	24.8	1.0	0	1.0	107
3226.1	25.0	3227.1	24.5	1.0	0.5	0.7	106
3201.1	26.4	3202.6	26.6	1.5	0.2	1.1	105
3174.7	26.3	3176.0	26.5	1.3	0,2	0.8	104
3148.4	29.3	3149.5	28.9	1.1	0.4	1.1	103
3119.1	27.4	3120.6	29.3	1.5	1.9	2.0	102
3091.7	33.5	3091.3	32.4	0.4	1.1	1.6	101
3058.2	35.6	3058.9	34.3	0.7	1.3	1.3	100
3022.6	38.3	3024.6	39.0	2.0	0.7	1.1	99
2984.3	37.5	2985.6	40.9	1.3	3.4	3.8	98
2946.8	26.0	2944.7	22.7	2.1	3.3	3.5	97
2920.8	23.0	2922.0	23.9	1.2	0.9	1.1	96
2897.8	25.6	2898.1	25.3	0.3	0.3	1.4	95
2872.2	26.1	2872.8	26.2	0.6	0.1	0.2	94
2846.1	29.4	2846.6	29.3	0.5	0.1	1.6	93
2816.7	33.1	2817.3	31.9	0.6	1.2	2.1	92
2783.6	34.3	2785.4	35.5	1.8	1.2	1.7	91

N.E. level	thickness	S.W. level	thickness	variation level	variation thickness	variation in thickness 4 corners	course
2749.3	38.5	2749.9	38.2	0.6	0.3	1.2	90
2710.8	22.7	2711.7	23.2	0.9	0.5	0.6	89
2688.1	23.1	2688.5	22.4	0.4	0.7	1.2	88
2665.0	21.9	2666.1	22.7	1.1	0.8	1.0	87
2643.1	26.3	2643.4	26.0	0.3	0.3	0.7	86
2616.8	22.9	2617.4	22.8	0.6	0.1	0.1	85
2593.9	27.8	2594.6	27.8	0.7	0	0.3	84
2566.1	22.6	2566.8	22.7	0.7	0.1	0.2	83
2543.5	23.3	2544.1	23.1	0.6	0.2	2.3	82
2520.2	23.2	2521.0	23.5	0.8	0.3	2.0	81
2497.0	24.1	2497.5	24.1	0.5	0	0.5	80
2472.9	23.1	2473.4	23.5	0.5	0.4	1.0	79
2449.8	23.7	2449.9	23.4	0.1	0.3	2.1	78
2426.1	25.5	2426.5	23.9	0.4	1.6	2.5	77
2400.6	23.6	2402.6	24.8	2.0	1.2	1.5	76
2377.0	29.0	2377.8	29.3	0.8	0.3	0.5	75
2348.0	30.4	2348,5	30.5	0,5	0.1	1.5	74
2317.6	25.3	2318.0	25.9	0.4	0.6	1.3	73
2292.3	25.8	2292.1	26.1	0.2	0.3	0.5	72
2266.5	28.8	2266.0	28.1	0.5	0.7	1.5	71
2237.7	27.8	2237.9	28.1	0.2	0.3	1.9	70
2209.9	32.4	2209.8	31.2	0.1	1.2	2.0	69
2177.5	30.6	2178.6	31.7	1.1	1.1	1.4	68
2146.9	35.0	2146.9	34.0	0	1.0	1.7	67
2111.9	23.7	2112.9	24.3	1.0	0.6	1.3	66
2088.2	26.2	2088.6	25.5	0.4	0.7	0.7	65
2062.0	25.6	2063.1	26.1	1.1	0.5	0.8	64
2036.4	26.0	2037.0	26.2	0.6	0.2	0.9	63
2010.4	24.4	2010.8	25.0	0.4	0.6	0.6	62
1986.0	26.2	1985.8	26.4	0.2	0.2	0.3	61
N.E. level	**thickness**	**S.W. level**	**thickness**	**variation level**	**variation thickness**	**variation in thickness 4 corners**	**course**
1959.8	28.1	1959.4	27.7	0.4	0.4	0.4	60
1931.7	28.7	1931.7	29.6	0	0.9	0.9	59
1903.0	28.6	1902.1	25.6	0.9	3.0	5.5	58
1874.4	22.5	1876.5	25.0	2.1	2.5	5.2	57
1851.9	24.8	1851.5	24.8	0.4	0	0.1	56
1827.1	25.3	1826.7	25.1	0.4	0.2	0.5	55
1801.8	25.7	1801.6	25.3	0.2	0.4	0.4	54
1776.1	25.6	1776.3	25.6	0.2	0	0.3	53
1750.5	26.3	1750.7	26.5	0.2	0.2	0.6	52
1724.2	26.6	1724.2	26.5	0	0.1	0.5	51
1697.6	28.0	1697.7	28.1	0.1	0.1	0.2	50
1669.6	31.2	1669.6	31.4	0	0.2	1.8	49
1638.4	35.5	1638.2	35.1	0.2	0.4	2.5	48
1602.9	35.6	1603.1	34.9	0.2	0.7	1.1	47
1567.3	27.3	1568.2	28.2	0.9	0.9	0.9	46
1540.0	37.9	1540.0	38.1	0	0.2	0.4	45
1502.1	41.1	1501.9	41.1	0.2	0	0.3	44
1461.0	33.3	1460.8	32.1	0.2	1.2	1.2	43
1427.7	28.0	1428.7	29.4	1.0	1.4	1.5	42
1399.7	30.9	1399.3	30.7	0.4	0.2	0.3	41
1368.8	31.9	1368.6	31.8	0.2	0.1	0.6	40
1336.9	33.9	1336.8	33.8	0.1	0.1	1.1	39
1303.0	36.3	1303.0	36.3	0	0	0.8	38
1266.7	38.2	1266.7	38.0	0	0.2	0.4	37
1228.5	41.1	1228.7	41.8	0.2	0.7	0.7	36
1187.4	49.8	1186.9	49.2	0.5	0.6	1.1	35
1137.6	26.2	1137.7	26.3	0.1	0.1	0.1	34
1111.4	26.3	1111.4	26.2	0	0.1	0.4	33
1085.1	26.3	1085.2	26.0	0.1	0.3	1.0	32
1058.8	27.8	1059.2	28.3	0.4	0.5	0.6	31

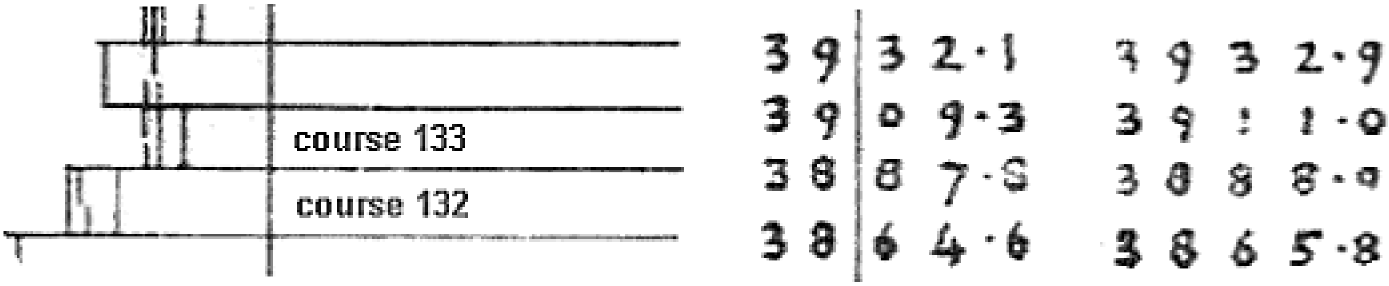
N.E. level	thickness	S.W. level	thickness	variation level	variation thickness	variation in thickness 4 corners	course
1031.0	28.2	1030.9	27.8	0.1	0.4	1.5	30
1002.8	28.1	1003.1	28.0	0.3	0.1	0.4	29
974.7	29.2	975.1	29.2	0.4	0	0.8	28
945.5	29.7	945.9	29.6	0.4	0.1	0.8	27
915.8	30.8	916.3	31.2	0.5	0.4	0.5	26
885.0	32.3	885.1	32.4	0.1	0.1	0.2	25
852.7	32.4	852.7	32.3	0	0.1	0.3	24
820.3	33.0	820.4	33.1	0.1	0.1	0.7	23
787.3	34.5	787.3	35.1	0	0.6	0.8	22
752.8	23.8	752.2	22.5	0.6	1.3	1.3	21
729.0	23.5	729.7	24.1	0.7	0.6	1.0	20
705.5	38.1	705.6	39.1	0.1	1.0	1.5	19
667.4	31.1	666.5	31.1	0.9	0	0.6	18
636.3	28.0	635.4	28.3	0.9	0.3	0.6	17
608.3	28.9	607.1	28.1	1.2	0.8	0.8	16
579.4	29.3	579.0	28.2	0.4	1.1	1.4	15
550.1	29.4	550.8	29.2	0.7	0.2	2.9	14
520.7	29.8	521.6	25.7	0.9	4.1	4.4	13
490.9	29.7	495.9	34.0	5.0	4.3	6.6	12
461.2	33.7	461.9	32.6	0.7	1.1	1.1	11
427.5	36.0	429.3	37.7	1.8	1.7	3.4	10
391.5	36.4	391.6	34.2	0.1	2.2	3.2	9
355.1	37.8	357.4	34.9	2.3	2.9	5.2	8
317.3	39.2	322.5	44.1	5.2	4.9	5.3	7
278.1	38.0	278.4	39.6	0.3	1.6	2.0	6
240.1	40.2	238.8	38.9	1.3	1.3	2.2	5
199.9	44.0	199.9	44.5	0	0.5	0.8	4
155.9	48.2	155.4	45.4	0.5	2.8	5.1	3
107.7	49.1	110.0	52.4	2.3	3.3	4.9	2
58.6	58.6	57.6	57.6	1.0	1.0	2.4	1

Continue

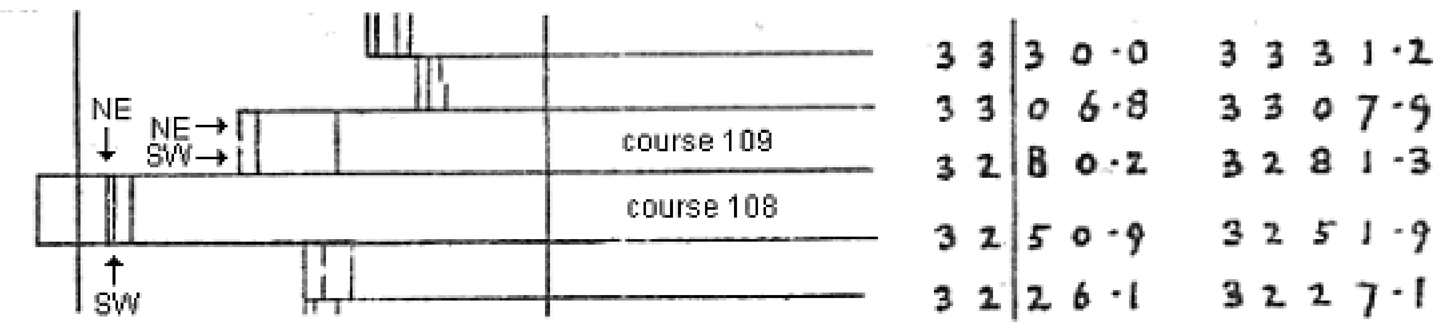
NOTES :

A. Petrie gave two levels for course 2. on the S.W. ie, 110.0 and 110.2. Only the first has been entered.

B. It was thought necessary to alter the S.W. level of course 132 from 3888.0 (as read by a number of investigators) to 3888.9 (illustrated below). The "level" data is for the top of each course. Petrie's thickness bars (to the left) for courses 132, 133 support the figure 3888.9, not 3888.0.

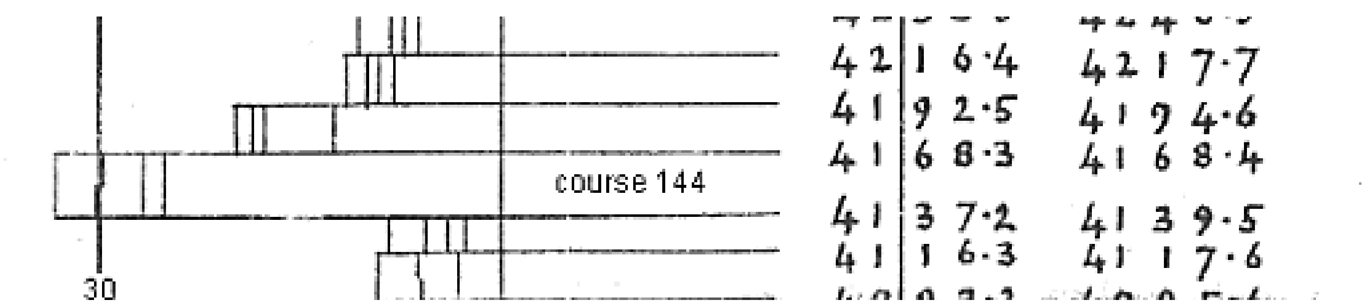


C. All of the horizontal thickness bars from the previous page have been re-measured and compared with Petrie' course levels, to see if, (1) they are correctly represented on the page, and, (2) to see if it can be found which bars relate to the NE and SW corners. As there is only one chance in six that Petrie's NE and SW data reflect the greatest thickness variation for each course most of the entries in the four corner column above will be greater than his. In some cases the total variation for individual courses far exceeds the data given by Petrie, courses 108 and 109 for example. In these two cases the NE and SW thicknesses have been identified as those represented by two bars very close together and greatly separated from at least one other.



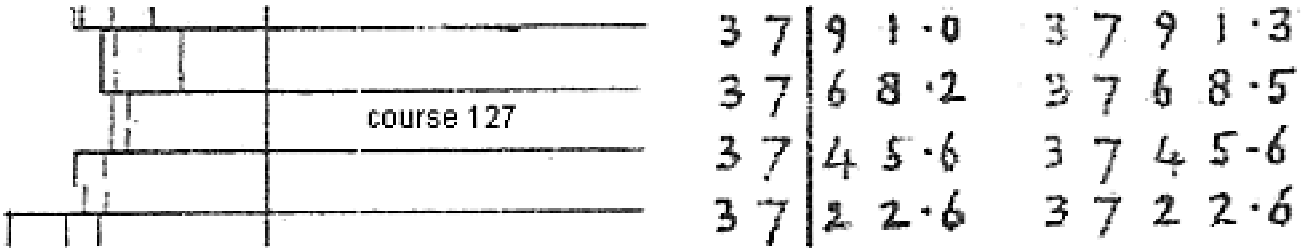
After looking at all the courses and their horizontal thickness bars the following was also found :

1. Course 144 has 5 corner entries marked in. The top bar (far left) is consistent with Petrie's NE reading and the bar second from the bottom the SW reading. Taking the bottom bar to be a correct entry the variation in thickness seems a little excessive (2.7 inches and the largest of the top 100 courses) so we suspect that this might be the odd one out. If not, then the other two corners of the pyramid are represented by the bottom bar and one of the two bars (?) hugging the 30 inch level.
Don't forget that the figures to the right of the illustration relate to level at the top of each course. Variation in thickness has to extracted, first, one over the other, and then across.

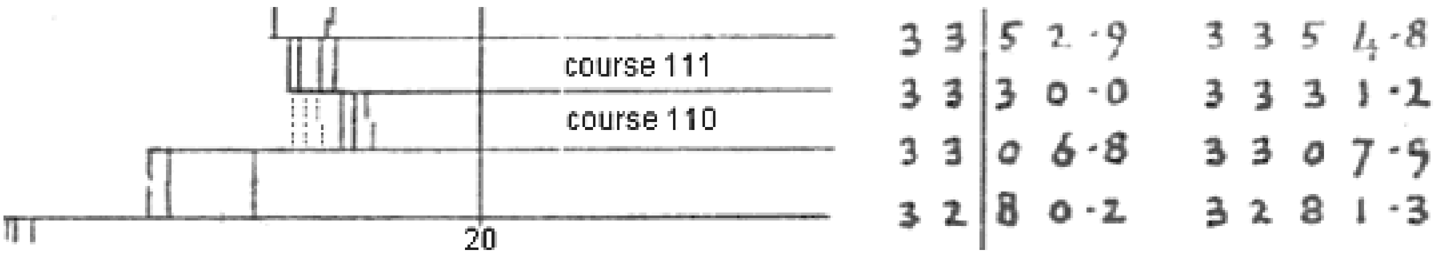


Continue

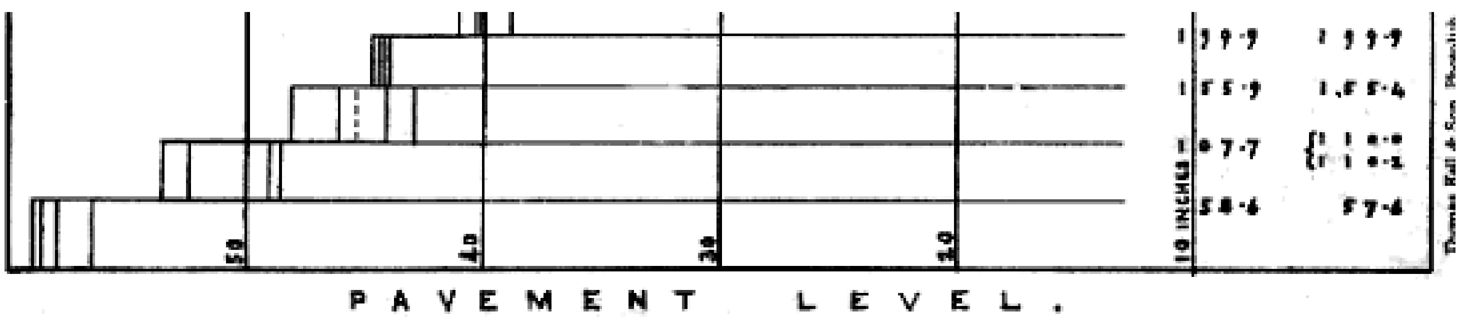
2. The missing bar for course 127 (Petrie's NE reading) should have been entered about midway between the bars illustrated



3. All the bars for course 110 have been wrongly placed. Petrie must have misread the distances 23.2 and 23.3 or 3,2 and 3.3 respectively above the 20 inch level. Our best guess is that all should be raised (as a block) to the dotted lines illustrated. It is presumed that the NE and SW thickness readings represent the two half bars 1/10th of an inch apart.



4. Course 3 ---- The top bar (far left) agrees with Petrie's level for the NE corner but the next bar underneath is wrong for the SW reading and should be lower as illustrated by the dotted line. The large variation in level across the platform (course 2) was corrected with course 3 (almost). Note the huge improvement with thickness when course 4 was laid.



The errors listed above are not the only ones. Minor bar placing discrepancies also occur for courses 124 and 125 and a number of other courses towards the base and it is here that we must realize the hazards of transforming columns and columns of data into illustrated bars.

Illustrations ... single page plates twice normal size.

Additional charts and illustrations of the Great Pyramid's courses