extent cut off from the sea (as at the 'Ain Feshkhah pool), but on the edge of the sea itself. Mr. Hornstein, who was with me, saw these fish independently. They are probably small cyprinodontidæ.

THE CONSTRUCTION OF THE GREAT PYRAMID OF GIZEH.

By Colonel C. M. Watson, C.B., C.M.G., R.E.

In an article which was published in the *Quarterly Statement* for July, 1899, entitled "The Ancient Standards of Measure," Sir Charles Warren discussed the knowledge possessed by the Egyptians of the properties of circles and squares with reference to the design of the Great Pyramid of Gizeh, but he does not appear to have noticed that the dimensions of the Pyramid, curious as they are, can be arrived at by a simple geometrical construction, and that if this construction had been laid out on the ground on a sufficiently large scale, no calculations were necessary to fix the various proportions.

The objects which appear to have been aimed at by the architect of the Pyramid are detailed in the ninth chapter of Professor Flinders Petrie's work, "The Pyramids and Temples of Gizeh." The principal of these were as follows :—

The base of the Pyramid was a square of 440 cubits side.

The height was equal to the radius of a circle, the circumference of which was equal to the perimeter of the base.

The floor of the great chamber, usually called the King's Chamber, was placed at a level above the base, where the area of a horizontal section was equal to half the area of the base of the Pyramid. The diagonal of the square at the level of the King's Chamber was equal to the side of the base, while the side of the square was equal to half the diagonal of the base.

The angle of descent of the entrance passage was at a slope of one over two, and the angle of the ascending passage and great gallery were nearly at the same angles.

I propose to show how these conditions can be met by a simple geometrical construction, and thus to point out how extremely near the results arrived at compare with the actual measurement as carefully made by Professor Petrie.

In the annexed diagram let the square ABCD represent the base of the Pyramid—AC is a diagonal and E the centre of the square.

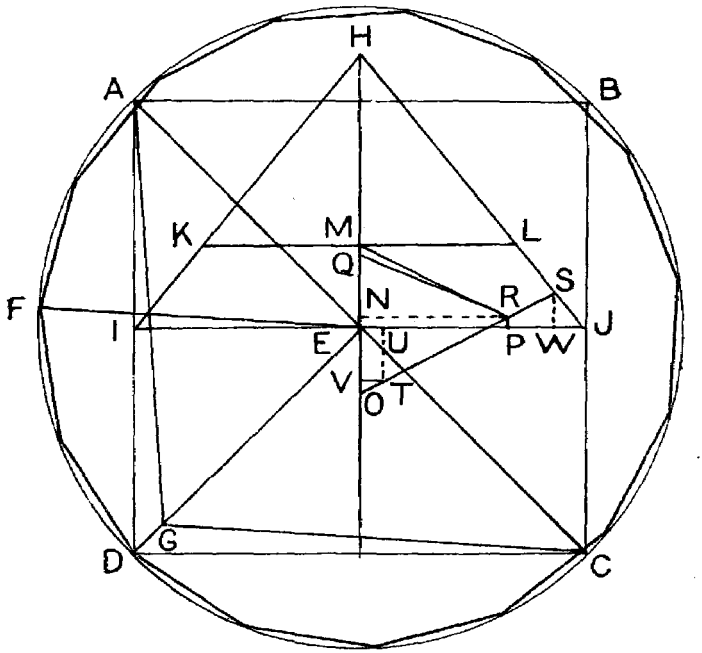
Describe a circle around the square, and in this circle inscribe an equilateral quindecagon ("Euclid," Book IV, Prop. 16) having an angle at D.

Join E to F, the second angle of the quindecagon from D. Draw CG parallel to EF and join AG. Thus will EG be the required height of the Pyramid, and AGC is the vertical section of the Pyramid on a diagonal of the base.

The proof is as follows :—

If the perimeter of the square ABCD was equal to the circumference of a circle of which EG was the radius, $2 \times AB = \pi \times EG$.

$\therefore EG = \frac{2}{\pi} AB$, and if we take $AB = 1$, then $EG = 0{\cdot}63662$.



The length of EG, as given by the geometrical construction, can be calculated as follows :—

As CG is parallel to EF, $CGE = GEF$, but as DF is by construction $\frac{2}{15}$ parts of the whole circumference, the angle $DEF = CGE = \frac{2}{15} 360° = 48°$.

But $\tan CGE = \frac{EC}{EG}$, $\therefore EG = \frac{EC}{\tan 48°}$.

But $EC = \frac{AB}{\sqrt{2}}$, or if, as before, we take $AB = 1$, $EC = \frac{1}{\sqrt{2}}$.

$\therefore EG = \frac{1}{\sqrt{2} \tan 48°} = 0{\cdot}63668$.

It will be seen, therefore, that the height of the Pyramid, as found by the construction, differs from the theoretical height by 0·00006 only, a difference much less than the probable amount of error in the construction of the masonry of the Pyramid.

But to proceed. Make EH equal to EG, and join IH, JH. Thus IHJ represents a vertical section of the Pyramid through the centre on a line perpendicular to the two opposite sides AD, BC.

Draw KL parallel to IJ, and equal in length to the half diagonal AE. Thus KML is a line on the level of the King's Chamber, and the level of this above the base is represented by the vertical line EM.

Make MN, NO, and JP each equal to one-third of EJ, which is equal to half the side of the base of the Pyramid. Draw NR parallel to EJ, and PR perpendicular to EJ meeting in R. Thus R is the point of junction of the descending and ascending passage floors.

Join MR. Join OR, and produce it to S in the line HJ, which represents the sloping side of the Pyramid. Thus MR represents approximately the line of floor of the ascending passage and great gallery, and OPS represents the floor of the descending passage. S is the point where the latter passage cuts the casing of the side of the Pyramid.

It will be seen from the construction that the passages are at the required slope of one over two.

Petrie has shown that the slope of the ascending passage and great gallery is rather less than one over two, and that the floor cuts the centre line of the Pyramid, not at M, but at point Q, which is 33·88 inches below M. He has also shown that the descending passage does not extend to the centre line at O, but that it turns in a nearly horizontal direction at the point T, the distance TV being 306 inches.

The angle of slope of the side of the Pyramid is EJH. The tangent of this angle is $\frac{EH}{EJ}$, and as both of these values are known, it is easy to calculate that EJH = 50° 51′ 24″. It is not necessary to go through the whole of the calculations, but it is evident that taking the data given above, the value of all the different lines in the diagram can be expressed in terms of AB, the side of the base of the Pyramid.

Professor Petrie calculated the value of the side of the base as being equal to 9068·8 inches, and has adduced good reasons for this value. He has, however, in another place given a length of 20·632 inches as the probable best value for the Egyptian cubit to be derived from the Pyramid, and has also stated his opinion that the length of the side was 440 cubits. But 440 × 20·632 = 9078·08 inches. If the latter value is correct, it would simply mean that the original base of the Pyramid was at a slightly lower level than that assumed by Petrie. As, however, I feel a little doubt as to which of the two values is most likely to be correct, I have shown them both in the annexed table, which gives the values of the most important of the Pyramid measures, as derived from the geometrical construction, compared with the actual values of

Table Showing Comparison of Measures found by construction with Actual Measures taken by Dr. Petrie.

Dimensions.	As lettered in Diagram.	Theoretical value, taking value of side of pyramid as given by Petrie.	Actual value as given by Petrie.	Theoretical value, assuming that the side is equal to 440 cubits of 20·632 inches
		Inches.	Inches.	Inches.
Length of side of base	A B	9068·80	9068·80 ± ·5	9078·08
Height of pyramid	E H	5773·90	5776·0 ± 7·0	5779·81
Height to level of King's Chamber..	E M	1691·61	1692·8 ± ·6	1692·88
Height to intersection of descending and ascending passage.	P R	179·14	179·9 ± ·2	179·87
Level of entrance to pyramid	S W	671·21	668·2 ± ·1	672·12
Horizontal distance of entrance from north side of base.	J W	527·11	524·1 ± ·3	527·83
Length of descending passage	S T	4137·89	4139·88	4138·93
Length of ascending passage and great gallery to step.	R Q	3365·17	3362·3	3368·00
Level below base of south end of descending passage.	U T	1178·33	1181·0 ± ·1	1180·14
Inclination of side of pyramid	E J H	51° 51′ 24″	51° 52′ 0″ ± 2′	51° 51′ 24″
Angle of descending passage..	N R T	26° 33′ 54″	26° 31′ 23″	26° 33′ 54″
Angle of ascending passage	N R Q	26° 13′ 1″	26° 12′ 50″	26° 2′ 59″

the same measures, as obtained from the Pyramid by Professor Petrie. Having regard to the care bestowed upon the subject by him, there can be little doubt that the actual measures are as accurate as could be obtained.

It will be seen, by an examination of the table, that the results obtained by taking the base as having a side of 6078·08, are, on the whole, rather nearer to Petrie's measurements than are those derived from a base of 6068·8 as given by him, but it would not be safe to conclude therefore that his base value is too small, as the differences in the values are so trifling that they might be due to errors in construction.

If the architect of the Pyramid had laid out the construction geometrically in the manner indicated above, it would evidently have been necessary for him to have had a smooth, level surface of considerable area to work upon. Such a surface existed on the east side of the Pyramid in the great basalt pavement, which was nearly 180 feet in length and covered more than a third of an acre. It seems to me probable that this pavement formed a gigantic drawing board, upon which the architect laid out the lines of construction of the Pyramid. The angular measurements were most probably laid out by means of the azimuth trenches, the axes of which meet on the west side of the pavement, while the angles of the Pyramid were worked out to full size in the trial passages, which lie to the north of the basalt pavement.

The basalt pavement would also probably have been used as the workshop for fitting together the masonry of the chambers and passages before these were hoisted into their proper places in the Pyramid. The casing stones, too, may have been cut to the proper angles and fitted together on the pavement, the position of which, at the end of the great causeway by which the stones were brought from the Turah quarries, was very conveniently situated for the purpose.

December 27th, 1901.

NOTES ON THE JORDAN VALLEY AND PETRA.[1]

By Professor WILLIAM LIBBEY, Sc.D.

1. THE paper discusses some of the geological features of the Jordan valley, and the connection between the Dead Sea and the Gulf of Akabah.

There seems to be less evidence of a fault with a subsidence upon its eastern side than was supposed. There was, however, undoubtedly a rift valley or fracture, which was widened at a later period. This valley extended from the foot of Mount Hermon southward.

[1] Abstracts of papers read before the British Association Meeting at Belfast, 1902. (Section E.)