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OBITUARY

We note here with regret the loss of the highly-esteemed scholar, Dr. I. E.S. Edwards, who found time to contribute to the pages of *DE*. Furthermore, many of the articles in our journal have been the result of his pioneering work on the pyramids.

We record here also the death of John Connaughton, architect, whose many unsigned illustrations have appeared on our pages mainly in the articles by Alessandra Nibbi. Our *DE* cover with the Roman lettering was chosen upon his advice.

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f) Our numbers are now filling early so that articles are often held over until the next number.

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A note on the geometry of the star-shafts in the pyramid of Khufu.

R.J. Cook

In a recent article (1), John A.R. Legon has argued against the 'stellar correlation theory', developed in the pages of this journal by Robert Bauval (2), as well dismissing the system of stellar geometry which I put forward in DE.29 (3). He continues to hold fast to the very dubious 'ventilation' theory to explain the significance of the shafts leading off from the King's and Queen's chambers inside the Great Pyramid. As a consequence he is enabled to discount astronomy in discussing the geometry of these, in my opinion more correctly termed, *star shafts*.

While Legon acknowledges that 'the patterning of the stars in Orion's belt must be said to resemble the broad disposition of the Giza pyramids' he notes that the orientation of the belt when referred to the meridian diverges from the corresponding alignment when referred to the ground, and finally rejects the belt correlation because he believes that pyramid-builders 'were acutely conscious of the natural orientation of star-fields'. Actually, the 'patterning' of belt stars correlates with the positions of the Giza pyramids too closely to be so easily dismissed and, while it is true that the belt orientation cannot be explained by supposing that it 'was intended to reflect the situation which, due to precession, would have existed in 10,450 BC', the curious orientation can be explained as a clever device employed by the builders to date the monument to epoch 2450 BC, as I have tried to show in a recent book (4). Nevertheless it must be agreed that the key to the stellar-correlation theory lies with the star shafts. But are we really to believe that four and a half thousand years ago the star Sirius (which all authorities agree was of supreme mythic importance to the ancient Egyptians) just happened to culminate in close alignment with a shaft (the southern shaft of the Queen's chamber) which, according to Legon, was built for 'reserve ventilation' and laid out solely according to a system of geometrical aesthetics?

It is difficult to understand why the Giza architect would have arranged these putative 'air shafts' to emerge at the same level - an air-conditioning system normally has the inlet at a higher level than the outlet (and there is also the problem that the ascending passage, which might have served as an additional conduit, was closed by the plug blocks which were probably 'built in'). There is also the fact that the Queen's Chamber shafts were closed at both ends, and much convoluted reasoning becomes necessary to explain this according to the 'air shaft' theory. (And it would seem that the King's Chamber shafts were closed at their upper ends, as well).

As to the layout of these shafts, Legon sees this as purely geometric. I had earlier noted (5) that if we take Gantenbrink's figure for the King's Chamber shaft mouth levels of 154 cubits then we can relate this to the vertical distance between the King's Chamber floor level and apex of 198 cubits. Legon makes the indeed interesting observation that the layout of the Queen's Chamber shafts can be related to this scheme. At the level of the King's Chamber floor, the diagonal of the pyramid cross-section is 440 cubits, equal to the side of the pyramid at its base. With a King's Chamber shaft mouth level of 126 cubits below apex, then the diagonal of this level is 280 cubits. The Queen's Chamber shaft mouth level is 148.5 (or 198 X 3/4) cubits below apex, and its diagonal is therefore 330 cubits. Legon further points out that this level is emphasised by one of the thick masonry courses (the 90th), thus making the startling implication that course heights were intentionally planned to achieve this result.

The course levels of Khufu diminish in thickness from bottom to top (today there remain 201 courses, having an average thickness of 0.69 m. Not knowing the dimensions of the capstone we can only guess at the original number). These courses are arranged in 20 groups, the courses within each group graded in thickness from bottom to top. Since the limestone at Giza is stratified into unequal layers, Goyon (6) believed that each group represented a separate batch of quarrying activity.

Petrie (7) tried to account for some aspects of pyramid design with a 'theory of areas' (for which he found support in 'Hindu temple geometry'). For example, the King's Chamber floor was placed at a level where the area of the horizontal section is half that of the base, and apparently marked by the top of the 50th course (which has average thickness). Petrie appeared to believe that course thicknesses had been intentionally planned, for he further maintained that 'thick' courses occur where the area of the horizontal cross-section is a multiple of fiftieths of the base area. However, this relation can only be made to work for a quarter of such boundaries and is not convincing. As to Legon's suggestion, that the Queen's Chamber shaft mouth level is marked by the surface of the thick 90th course, then why are levels of the King's Chamber floor and shaft mouths not marked by thick masonry courses as well? (And should not the Queen's Chamber floor have been so placed that the diagonal of its level would also give a significant number of cubits?).

Course heights may have been 'adjusted', for the levels of the King's, Queen's, and Ante-Chamber roofs roughly correspond to course levels, but the argument for precise planning of courses (and the awesome logistics this would entail) requires an explanation for every thick course if it is to be convincing. The 35th course is the most prominent in the pyramid - a level *not exactly in its middle* divides the pyramid into two equal volumes. Whereas, in this case, it does seem that a level has been intentionally emphasised by a thick masonry course, the level of the course top does not appear to be significant.

The discrepancy between Gantenbrink's figure for the King's Chamber shaft mouth level (of 154 cubits) and Petrie's (152 cubits) is surprisingly large and Legon therefore concludes that Petrie miscounted the stone courses. However, Gantenbrink has reported that the starshafts are not straight but increase in angle from bottom to top (but as yet has supplied no details). As a consequence we may put forward alternative, or complementary geometric schemes (and at Giza we are presented with other examples of initial schemes replaced by 'final' schemes - as in the layout of the Khufu passage system, as well as the modifications to Legon's plan which I have described elsewhere (8)).

Previous estimates of the angles of the lower ends of the Queen's Chamber shafts had been in the 38° range (and Legon had previously noted that the Queen's Chamber shafts are approximately at right angles to the pyramid casing, requiring a theoretical angle of 38°9'26"). Gantenbrink's mean for the south shaft is 39.5°, so the increase in angle is quite considerable. The common angle for the Queen's Chamber shafts required by Legon's scheme, given by the gradient 14/17, is 39°28'21". While this figure agrees well with Gantenbrink's figure for the Queen's Chamber south shaft, it is too large for the north shaft. (And it does not agree with the alignment to Kochab at 39°, which of course is unimportant to Legon).

The system of starshaft geometry put forward by the present writer is based upon a module of 200 cubits - exactly one tenth the side of the Giza layout square, and equal to the vertical module in the design of the bent pyramid of Dashur (9). The merit of this scheme of stellar geometry is that it unites all four starshafts, *and the ascending passage*, into one very simple scheme, which is impressive enough even without the stellar correlation and certainly beyond the power of the present writer to invent. But admittedly, if it is to be really convincing, it should also explain the layout of the descending passage.

In his analysis of the Khufu passage system (10) Legon showed that the descending passage had been laid out such that the horizontal distance between the intersection of the passage floor and that of the ascending passage (at E in the accompanying figure) and the north base of the pyramid (at B) is 73.6 cubits.

The basis of the scheme of starshaft geometry put forward by the present writer was a 'model pyramid' with height 327.27 cubits and half-base of 257.2 cubits - the line of the ascending passage defined by the line YZ in the figure. This pyramid is inverted, and the point of intersection of its sloping side with the line of the ascending passage (at A), in turn establishes the points B, C, D, and E. The distance BC becomes 73.7 cubits - in close agreement with Legon's figure.

(1) Legon, J.A.R. 1995. 'The Orion Correlation and Air-Shaft theories'. *DE.33*.
(2) Bauval, R.G. 1989. 'A Master Plan for the Three Pyramids of Giza based on the configuration of the Three Stars of the Belt of Orion'. *DE. 13*. and further papers.
(3) Cook, R.J. 1994. 'The Stellar Geometry of the Great Pyramid'. *DE. 29*.
(4) Cook, R.J. 1996. *The Horizon of Khufu*. London.
(5) See reference 3.
(6) Goyon, G. 1978. 'Les Rangs d'Assises de la Grande Pyramide'. *Bulletin de l'Institute Francais d'Archaeologie Orientale*.
(7) Petrie, W.M.F. 1883. *The Pyramids and Temples of Gizeh*. London.
(8) See Legon, J.A.R. 1989. 'The Geometry of the Great Pyramid'. *Gottinger Miszellen*. 108. Also Cook, R.J. 1995. 'The elaboration of the Giza site-plan'. *DE. 31*.
(9) Legon, J.A.R. 1990. 'The Geometry of the Bent Pyramid'. *Gottinger Miszellen*. 116.
(10) See reference 8.