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OBITUARY

We announce with great regret the loss of one of our most enthusiastic contributors, Professor Mostafa El Alfi, of the University of Benha, Egypt. Our sympathy goes out to his wife and family.

Professor El Alfi left us a number of articles for publication. These will continue to appear in our journal for some time to come.

Alessandra Nibbi

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(f) Our closing dates are the last day of March, July and November. However, our numbers are now filling early so that articles are often held over until the next number.

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THE AIR-SHAFTS IN THE GREAT PYRAMID

John A.R. Legon

With the recent exploration of one of the air-shafts in the Great Pyramid of Giza, carried out by Rudolf Gantenbrink for the German Archaeological Institute in Cairo using a remotely-controlled robot fitted with a video camera,[1] it is time to review the various arguments which have been put forward to explain the function of these curious shafts or channels, and to consider the implications of the latest discoveries for the design and construction of the Great Pyramid.

The air-channel in question leads horizontally southwards through the south wall of the Queen's Chamber for a distance of about 2 metres, with a cross-section of about 20 cm square, before turning upwards with the same cross-section at an angle of about 38 degrees.[2] Previous to Rudolf Gantenbrink's investigation, it was not known how far this shaft extended through the core-masonry of the pyramid; and it had been assumed that the channel had been abandoned with a change of the pyramid's design. Despite several attempts, the outer end had never been located in the outer face of the pyramid - a fact which is also true for the second, very similar channel, which leaves the Queen's Chamber from a point exactly opposite in the north wall, before ascending at about the same angle of slope.

The apertures of both channels had been hidden in the wall-surface of he chamber behind thin 'plates of stone', at a height of 1.6 ms from the loor. They were discovered in 1872 when the civil engineer Wayman Dixon, naving had his attention drawn to a small crack in the south wall, probed the crack with a wire and found empty space behind it.[3] The stone surface was broken through into the channel with a few strokes of a chisel, and a search was made in the north wall for the second aperture, which was duly discovered directly opposite the first. Inside these apertures were found a small piece of wood, a copper hook, and a stone ball - objects no doubt accidentally dropped down the channels by workmen during the construction.

In an attempt to locate the outer ends of the channels, fires were lit inside the openings at the lower ends in the hope that smoke would be seen issuing out through the sides of the pyramid.[4] Although no outlets were found, however, soot was deposited along the channels for some distance, and it is only in the upper section of the southern shaft that the masonry can still be seen to be composed of fine white limestone. Besides being

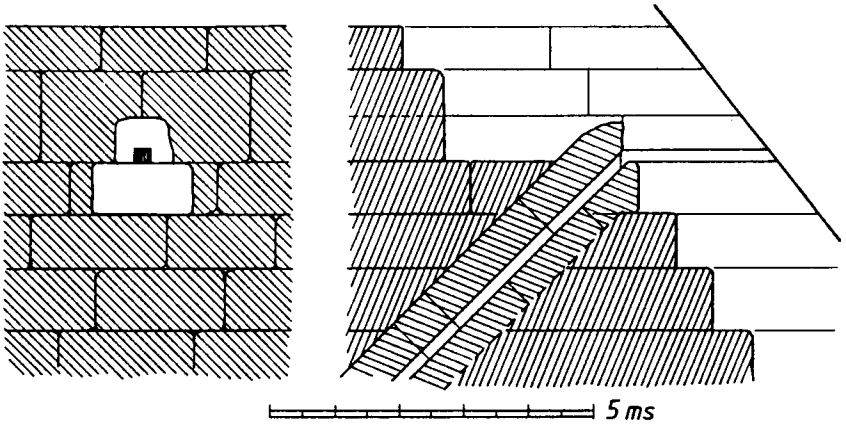

Fig.1 Exit of Southern Air-Shaft from King's Chamber (after Perring).

blackened with soot, the lower part of this shaft has a rough appearance which is certainly caused by an incrustation of salts, similar to those recently removed from the walls of the Queen's Chamber itself.[5] It is now known that the channel has a length of about 65 metres, and ends with a small limestone plug to which were attached two copper fitments.

These channels are similar in character to those which have been known in the King's Chamber since the earliest days of pyramid exploration, but which differ in having been carried completely through the wall-blocks of the chamber at the height of the first course. Although it can no longer be proven, there is no reason to doubt that the channels from the King's Chamber were open also at their upper ends, and continued outwards through the casing of the pyramid. According to Perring, who examined the joint with the casing-block (see fig. 1), the southern channel curved downwards and continued horizontally outwards for about 3 ms along the bedding-joint of the casing-block, 'probably with the view of preventing the sand from choking it up.'[6] The channel was thus cut into the underside of a casing-block following the inverted-trough and bedding-block construction used to extend the channels through the core-masonry. Petrie, however, thought that the channels had been continued outwards through the casing at their angle of slope - an arrangement which would have let rain water drain into the openings, besides being more difficult to construct.[7]

The fact that the apertures of the channels in the Queen's Chamber had been concealed in the wall-surface has been supposed to support the theory that the chamber was abandoned owing to a change of plan.[8] It is difficult

to see any justification for this argument, however, since it would have been much easier for the masons to cut the channels all the way through the wall-blocks, than to leave a thin plate of stone remaining in the surface. A cross-section through the apertures published soon after their discovery shows that the ends in the wall-blocks had been worked in a curve to within about 2 cm of the wall-surface,[9] thus suggesting that the purpose had been to leave the apertures in such a condition that they could easily be broken through if the need arose. It is now known that the southern channel ends at about the same level as the final relieving compartment above the King's Chamber, showing that the channel itself - and hence the Queen's Chamber also - was not simply abandoned when work on the King's Chamber began.

The Stellar Destiny of Pharaoh

Now turning to the purpose of these shafts or channels, by far the most generally-accepted theory has been that they served in the funerary cult, by providing a passageway for the spirit or *ba* of the late king to ascend to the heavens.[10] In particular, the northern channels are thought to have been aligned towards the circumpolar stars, while the southern channels were directed towards the constellation of Orion and to Sirius. Although attractive, however, this theory has a number of severe disadvantages to which too little attention has been paid in the past.

Firstly, while the northward-ascending Entrance Passage in the Great Pyramid pointed to the region of the north celestial pole, and so towards a group of stars which were always in broad alignment with the passage at any time during the day or night - the circumpolar or 'imperishable' stars referred to in the Pyramid Texts - an alignment between one of the southward ascending channels and any given star took place only at culmination for a few minutes during every 24 hours. The stars in the Belt of Orion, for example, passed over the southern channel from the King's Chamber in less than ten minutes. This channel would therefore have been of doubtful value as a guide towards the stars, since it almost always pointed to a part of the sky which had no particular relevance in the stellar cult.

It may also be questioned whether the southern shafts should have been directed towards Orion's Belt or to some other star in the region of Orion. In the Pyramid Texts, the king in the guise of Osiris is referred to as a 'Companion of Orion' or a 'Dweller in Orion', who 'ascends with Orion from the eastern region of the sky' and 'crosses the sky with Orion'; but he is less certainly to be identified with the constellation itself.[11] Even when

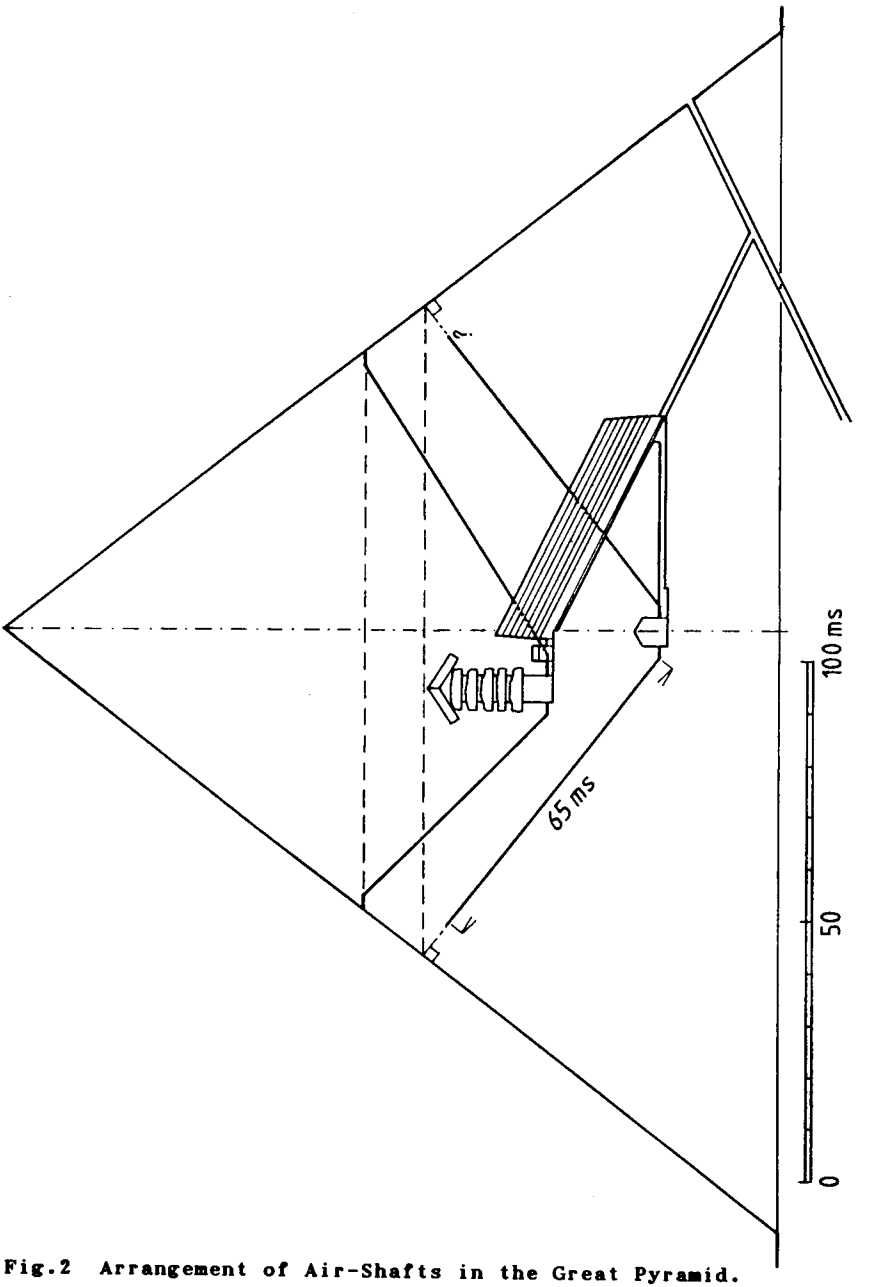

Fig.2 Arrangement of Air-Shafts in the Great Pyramid.

this equation appears to be made, the difficulty is probably grammatical; and it seems that the king was identified with a particular star in or near Orion, but not with the constellation as a whole. Faulkner supposed that the star might be Procyon - the brightest star in this region of the sky after Rigel and Sirius, which rose on the eastern horizon a few minutes after Orion had come into full view, and roughly half an hour before the appearance of Sirius.[12] The name *Sahu* = Orion may be translated, however, as the 'Toe-star', with probable reference to the brilliant Rigel at the foot of the constellation of Orion;[13] but neither Procyon nor Rigel would have formed any alignments with the shafts in the Great Pyramid.

A more serious difficulty arises from the actual angles of the shafts, which were certainly determined by practical convenience, and the desire for a systematic design. The fact that the two channels leading from the Queen's Chamber have almost the same angle of slope in itself throws great doubt upon the significance of any astronomical alignments, since it is unlikely that an alignment to a star or constellation in the northern sky, would have required the same inclination as an alignment to a star in the southern sky. Because the Queen's Chamber is situated in the exact centre of the pyramid, however, this equality of angles meant that the shafts would have emerged at the same level in the north and south sides of the pyramid (see fig. 2). From Petrie's survey we find:[14]

Shafts from Queen's Chamber,	North	South	Mean
Angle of Slope	37° 28'	38° 28'	37° 58'

The small difference in the angles of these channels, as taken by Petrie at their lower ends, may be explained by the fact that the builders did not attempt to align the shafts with any great precision.

In selecting this angle of slope, the intention of the architect was certainly to obtain the shortest possible length for the shafts from the Queen's Chamber to the outside of the pyramid - a requirement which was satisfied by making the incline of the shafts equal to the inverse of the pyramid's casing-angle, or just 11 rise on 14 base in place of 14 rise on 11 base. The line of the shafts then intersected the face of the pyramid with an angle of 90°. The mean angle of the two channels corresponds to this profile with a difference of only about ten minutes of arc:

Angle of Slope, for 11 rise on 14 base = 38° 9' 26"

In view of this very simple and obvious design principle, that the shafts should take the shortest route to the outside of the pyramid, the claimed astronomical alignments must be considered coincidental.

This ideal angle of slope would no doubt have been chosen also for the shafts from the King's Chamber, but for the fact that this chamber is set to the south of the pyramid's central axis. The channels would then have come out at different levels on the north and south sides of the pyramid. It was certainly to avoid this situation that the builders compensated for the offset of the chamber, by increasing the angle of the southern channel while reducing the angle of the northern channel by the same amount. As a result - extending the slope of the shafts to meet the line of the casing - the difference in the level of the outlets was reduced from about 10 ms to only 60 cm; but since the shafts passed horizontally through the casing-blocks, they would probably have emerged in the 102nd course at the same height of exactly 150 cubits above the base on both sides.[15] The following angles were obtained by Petrie in the outlets of the channels:[16]

Shafts from King's Chamber,	North	South	Mean
Angle of Slope	31° 33'	45° 14'	38° 23'

Petrie observed that these channels became increasingly steep towards the outside of the pyramid, and believed that the angles would not have been greater than 31° and 44.5° overall. Even so, the mean is close to the theoretical ideal, and the angles gave practically the shortest possible distances which could be taken to the outside of the pyramid, consistent with the requirement that the openings in the casing should be situated at the same level on the north and south sides (see fig. 2).

While the theoretical angle which was employed for the northern shaft from the Queen's Chamber is about 8° too steep to have given an alignment with the north celestial pole, the northern shaft from the King's Chamber may be said to have formed an approximate alignment - the altitude of the pole being about 30° at the latitude of the Great Pyramid. It is clear, however, that this result came about coincidentally with a reduction in angle with respect to the geometrical ideal, which was intended to give the same level of outlet as the southern shaft. The increase in the angle of the southern shaft, similarly, resulted in the fortuitous alignment with the culminating stars in Orion's Belt. Again, while the southern shaft from the Queen's Chamber may be thought to have been aligned towards Sirius, it is evident that the angle of slope, like that of the northern shaft from the Queen's Chamber, was actually chosen to give a direction at right angles to the face of the pyramid.

The wide curving detours which the northern channels perform to avoid the masonry of the Grand Gallery, and the fact that they begin (and would

have ended) with horizontal sections, are further reasons for excluding the possibility of any astronomical alignments. Nonetheless, it might still be argued that the shafts were directed towards the sky in a general sense, and were intended to guide the spirit of the king in his ascent towards the stars. To this cultic interpretation there remains the serious objection that these shafts are to be found only in the Great Pyramid. Clearly, if such facilities had to be provided in one pyramid, then we should expect to find something similar in many other pyramids; but in fact, only the beginnings of channels are to be seen in the Second Pyramid of Giza.[17]

To overcome this difficulty, it has been supposed that the shafts in the Great Pyramid were necessary because the system of ascending passages removed the direct link between the burial chamber, and a passage which pointed towards the circumpolar stars.[18] This hypothesis, however, could only account for the northern channels in the Great Pyramid, leaving the need for southward-ascending channels insufficiently explained. Since in the Second Pyramid, the passage-system conforms to the standard pattern, the northern channel from the burial chamber could not have been started as a substitute for the entrance passage; and hence the argument that the northern channels in the Great Pyramid might have served this purpose is thrown into question.

While noting the existence of slots in ka-doors, and other features which might be conjectured to have provided a passageway for the spirit, Alexander Badawy was unable to point to examples of channels directed to the stars in any other pyramid or tomb or the Old Kingdom.[19] The notion that the *ba* of the king required a physical passage to pass through is in any case contrary to everything we know about the Egyptian way of thinking in such matters. A people who believed that the spirit of the king could pass through the solid core-masonry of his pyramid to visit his offering-temple on the one hand, did not need to provide a real physical means to assist the king in his journey to the stars on the other. The fact that in the Queen's Chamber, no indication whatsoever was provided in the wall-surface to show the positions of the shafts, even though the shafts were constructed in actuality in the masonry behind, is the complete reverse of the customary arrangement, whereby the representation of a false-door in the wall-surface was considered sufficient to allow the spirit of the deceased to pass through the solid masonry behind. Whatever magical means were necessary to enable the spirit of the king to ascend to the stars in other pyramids, would obviously have sufficed in the Great Pyramid also.

The Channels as Air-Shafts

If a cultic interpretation for the channels in the Great Pyramid is to be excluded, then we must turn to the physical purpose which is implicit in the need for a physical construction. The writer here agrees with Lauer[20] and also with Maragioglio and Rinaldi, who were 'reasonably sure that the air channels had a practical purpose and more so during the construction of the pyramid than after.'[21] This purpose was first clearly established through the efforts of Howard Vyse to unblock the channels leading from the King's Chamber; for once the last stone had been removed from the southern channel, Vyse observed: 'an immediate rush of air took place, and we had the satisfaction of finding that the ventilation of the King's Chamber was perfectly restored, and that the air within it was cool and fresh.'[22]

The adequacy of the ventilation in the Great Pyramid must have caused some concern for the builders because of the design of the passage-system; for unlike any other pyramid except the satellite pyramid at Dahshur, the arrangement of the ascending passages meant that hot spent air from burning oil-lamps and torches would have accumulated in the upper chambers, having no possible means of escape owing to the hermetically-close jointing of the masonry. The builders could not predict in advance whether the slight flow of air through the Descending and Ascending Passages would be sufficient to allow the various constructional tasks and the final funerary rites to be completed inside the pyramid; but it was a risk which they were certainly not prepared to take. The requirement for ventilation would however have been less in the Queen's Chamber, both during the construction while the Grand Gallery was still open and at the time of burial; and the tentative provision of air-shafts in this chamber may have been partly a precaution against the inadequacy or failure of the main ventilation system through the King's Chamber. Being devoid of any cultic significance, the openings in the Queen's Chamber were therefore concealed in the wall-surface - a measure typical of the extreme caution which was exercised throughout the design and construction of the Great Pyramid.

By the time the topmost relieving compartment above the King's Chamber had been roofed over and sealed, the builders could be reasonably certain that the flow of air through the channels in the King's Chamber would be sufficient to keep the entire passage-system adequately ventilated; and it was at this stage, as we now know, that work on the southern channel leading from the Queen's Chamber was finally brought to an end. The thin plates of stone concealing the apertures in the walls were therefore not

broken open, and the fine masonry of the chamber remained unspoilt.

A similar explanation will also suffice for the channels begun in the Second Pyramid; for although the passage-system in this pyramid is quite conventional, the burial chamber is still a considerable distance from the outside air; and the success of the ventilation in the Great Pyramid may have encouraged the builders to repeat the experiment. Thus trenches had to be cut in the rock on either side of the chamber, to connect with the channels which had been started high up in the rock-cut walls. After the roofing-beams of the chamber had been put in position, however, it would have been found that the circulation of air through the system of two entrance passages was sufficient to keep the chamber ventilated also; and hence there was no need to continue the channels any further.

The Closing of the Air-Shaft

In conclusion, we must consider the significance of the limestone block which was inserted in the upper end of the shaft leading from the Queen's Chamber. This plug appears to have been fitted without any mortar and is possibly removable; yet it can hardly be described as a portcullis-block since it measures only 20 cm across. There can be little doubt that this plug is merely the stopper which was used by the builders to close off the opening of the channel while it was exposed in the core-masonry during the construction of the pyramid. It would have been necessary to have some temporary means of plugging the opening, to prevent masons' debris from falling in and to keep out wind-blown sand. A tapered stone block would have served this purpose; and as we now know, holes were drilled through the block to take copper rods which were bent down flat on the inner side. On the other side, however, these rods were probably bent into loops or handles to make it easier to pull the stopper out when it was required to extend the channel through another course of masonry. It would have been natural to leave this stopper in place when the channel was abandoned and finally covered over with core-masonry.

If the shaft had been continued out through the casing of the pyramid, then the total length from the foot of the slope would have been 72.9 ms, with a possible maximum of 73.4 ms if we can credit the recent report that the angle increases at some stage to almost 45°. Since the actual length of the shaft is reported to be 65 ms, it follows that the upper end is only about 8 ms away from the line of the casing, or approximately 6 ms from the outside of the core-masonry. The construction of even a small

chamber in this position is, I believe, out of the question; and it is unfortunate that speculations as to the existence of a chamber may result in needless damage being inflicted upon the fabric of the Great Pyramid.

J.A.R. Legon, 3/6/1993

[1] Reports in The Daily Telegraph (7/4/1993); The Independent (16/4/1993 and 17/4/93); The Times (17/4/1993).

[2] W.M.F. Petrie, The Pyramids and Temples of Gizeh (London, 1883), 70-1.

[3] C.P. Smyth, Our Inheritance in the Great Pyramid (London, 1880), 427-9.

[4] Ibid., 428.

[5] Z. Hawass, appendix to Petrie, op.cit. (reprint, 1990), 103.

[6] J.S. Perring, The Pyramids of Gizeh, Vol.1 (London, 1839), 2; pl. IV. The end of the channel was probably destroyed when the surrounding masonry was blasted away by Howard Vyse, op. cit. (n. 22), 273.

[7] Petrie, op.cit. pl. XI.

[8] I.E.S. Edwards, The Pyramids of Egypt (Harmondsworth, 1991), 104.

[9] Smyth, op.cit., pl. XI. Smyth gives a thickness of 5 inches.

[10] A. Badaway, Mitt. Inst. Orient. Band X, Heft 2/3 (1964), 189-206; V. Trimble, Mitt. Inst. Orient. Band X, Heft 2/3 (1964), 183-188. See also Edwards, op.cit. 284-5; R. Stadelmann, Die grossen Pyramiden von Giza (Graz-Austria, 1990), 137-8.

[11] Pyr. 186, 723, 819, 882.

[12] R.O. Faulkner, The Ancient Egyptian Pyramid Texts (Oxford, 1969), 155.

[13] Badawy, op.cit., 201; K. Sethe, Übersetzungen und Kommentar zu den altägyptischen Pyramidentexten, Band III, 334.

[14] Petrie, op.cit. 71.

[15] The course-level is 3091.5 ins.; compare Petrie, op.cit. pl. XI with Perring, op.cit. pl. IV.

[16] Petrie, op.cit. 83.

[17] Ibid. 106.

[18] I.E.S. Edwards, in W.K. Simpson and W.M. Davies, Studies in Ancient Egypt, the Aegean and the Sudan (Boston, 1980), 55-57.

[19] Badawy, op.cit. 191-2.

[20] J-Ph. Lauer, Le Problème des Pyramides d'Égypte (Paris, 1948), 58.

[21] V. Maragioglio and C.A. Rinaldi, L'Architettura Delle Piramidi Memphite (Rapallo, 1965), Parte IV, 130.

[22] H. Vyse, Operations carried on at the Pyramids of Gizeh in 1837, Vol.1, (London, 1840), 286.