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Astronomical Investigation Concerning the So-Called Air-Shafts of Cheops' Pyramid

The pyramid of Cheops at Giza is unique among the monuments of Egypt in several ways. Not only is it the largest, best built, and most thoroughly surveyed of the pyramids, but it possesses several archi-

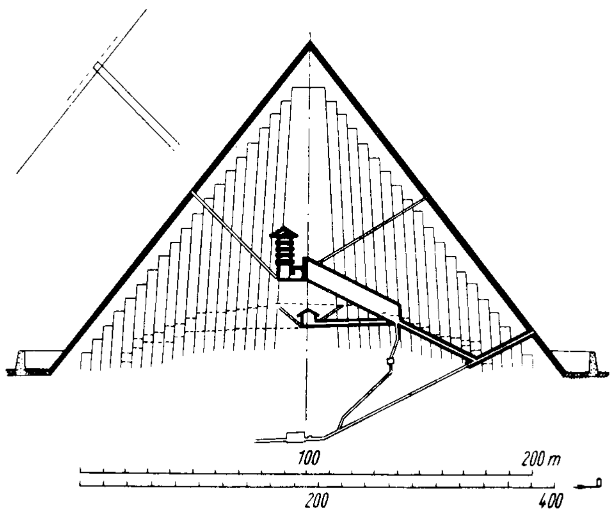

Fig. 1. Vertical cross-section North-South of Cheops' Pyramid

tectural features not found elsewhere. Among the most obvious of these are two shafts leading north and south out of the King's Chamber and slanting up to open on opposite faces of the monument (Fig. 1). Although the northern shaft makes an average angle with the horizontal of about 31° and the southern one an angle of $44^1/_2$°, because the King's Chamber is located south of the vertical axis from the apex of the pyramid, the two shafts open nearly at the same height on the northern and southern faces.[1]

The purpose of these shafts has not been determined, but it has frequently been held that they were intended simply for ventilation, hence the name "air shafts". In view, however, of the profoundly religious character of the pyramids themselves for the ancient Egyptians it seems not unreasonable to look for some deeper meaning to the shafts. It is the purpose of this paper to consider briefly some of the evidence for the view that the shafts were intended as ways whereby the soul of the deceased king might ascend to the north circumpolar stars and to the constellation now known as Orion. Although similar shafts do not appear to exist elsewhere there is ample evidence for the presence of slots and apertures intended to allow the soul of the deceased to pass through various walls. Such apertures first appear in the Third Dynasty tomb of Djeser[2] and become a regular feature in the serdabs of the Fifth Dynasty mastaba tombs[3].

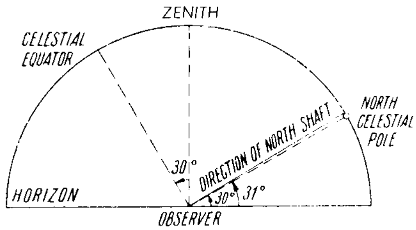

Fig. 2. Direction of north shaft and position of pole in sky for latitude 30° North

A notable feature of the religion of early Egypt was the "stellar destiny" of the soul, wherein it was thought that the soul of the dead king would rise to join the circumpolar stars – "The Indestructible Ones" or "The Imperishables" to the Egyptians – in their eternal journey around the sky. It is believed that the stairways or ramps desending from the north in Archaic mastaba tombs were intended to aid the soul in its ascent to these stars. That the north shaft of the pyramid might have served a similar purpose is made more probable by its inclination. The latitude of Giza is about 30° north (29°58′ 51″), and we recall that the north shaft makes an angle of 31° with the horizontal. This means that the shaft points very nearly toward the north celestial pole, about which the circumpolar stars seem to revolve (Fig. 2). It is also of interest to note that, at the time the pyramid was built, the pole war marked by a bright star about as accurately as Polaris (α Ursae Minoris) now marks it.

[1] W. Fl. Petrie, *The Pyramids and Temples of Gizeh*, 1883, p. 53.

[2] W. S. Smith, *The Art and Architecture of Ancient Egypt*, Penguin Books, 1958, p. 30.

[3] Alexander Badawy, *A History of Egyptian Architecture*, I, Giza 1954, p. 163.

It is generally known that the inclination of the earth's axis of rotation to the plane of its orbit (ecliptic) at an angle of about $23^1/_2°$ combines with the non-spherical shape of the earth and the gravitational force of the sun, moon and planets to produce a phenomenon known as the precession of the equinoxes. The effect of the sun and moon is to change the direction to which the earth's axis of rotation points relative to the fixed stars, while that of the planets is to change the plane of the earth's orbit relative to these stars. These effects are known as luni-solar precession and planetary precession respectively. It is evident that both factors will change the identity and positions of stars visible from a given point on the earth and that we must take them both into account when determining how the sky looked to the ancients.

In this scheme of moving stars, pole stars are a rather rare occurrence. In fact, after Polaris ceases to mark the pole in a few hundred years, there will not be another good one until α Draconis returns around A. D. 23000[4]. It happens, however, that the last "visit" of α Draconis to the neighborhood of the pole occurred from about 3000 to 2500 B. C.[5]. This means that the Egyptians of the pyramid age were more aware than might otherwise have been the case of the apparent daily journey of the stars about a fixed point in the sky. It thus seems highly probable that they would have chosen to build a shaft that would allow the soul of their dead king to ascend directly to this central point.

Non-circumpolar stars were also of considerable importance to the Egyptians. They measured time at night by means of decans – stars or groups of stars which rose or culminated (reached their highest elevation above the southern horizon) at one hour intervals during the night. Many of these decans were parts of constellation pictures (though different from ours which are derived from the Babylonian ones) and were identified with various gods. Very few of these have been identified with particular stars with any degree of certainty. There are, however, four of the 36 standard decans and five variants thereof which are parts of the constellation *Šꜣḥ* – "The god who crosses the sky" – whose identification with Orion "must be taken as likely in the highest degree"[6]. He is depicted as a man standing, looking back over his shoulder and holding

[4] Although α Cephei and α Lyrae (Vega) will come within about 4° of the pole in A. D. 7500 and 14000, they will not be nearly as accurate pole stars as Polaris and α Draconis, whose closest appraches to the pole are only about 30′ away.

[5] Robert H. Baker, *Astronomy*, New York 1950, p. 57.

[6] Otto Neugebauer and Richard A. Parker, *Egyptian Astronomical Texts*. I. The Early Decans, London 1960, p. 25.

a scepter in one hand and an *ʿnḫ* sign in the other. One of the five variants is probably the "belt" of *Sȝḥ*. Three of the decans intended for use during the epagomenal days appear also to have been parts of this constellation[7]. We may note as evidence for the identification the ceiling of the tomb of Senmut, in which the column devoted to *Sȝḥ* includes three large stars arranged vertically and bearing a striking resemblence to the three stars we call Orion's belt (δ, ε and ζ Orionis) which they probably represent.

The next relevant question is, of course, the position of these stars relative to the southern shaft at the time the pyramid was built. This requires calculations to allow for the two types of precession previously noted. We observe first that, because the shaft is directed due south, it can only point to a star at culmination, and we see that for a latitude 30° north and the inclination of the shaft, $44^1/_2°$, an appropriate star must have a declination (angular distance from the celestial equator) of $-15^1/_2°$ (Fig. 3). The question is then reduced to whether or not the stars of Orion ever had such a declination and, if so, when.

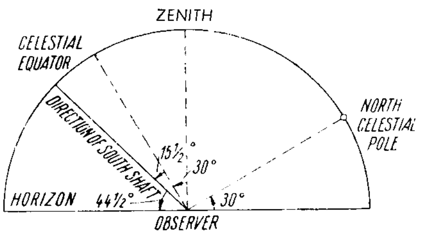

Fig. 3. Direction of south shaft in sky relative to positions of Pole, Equator and Zenith

It can be shown by spherical trigonometry that, for a star at declination δ and right ascension α (angular distance from the vernal equinox measured eastward along the celestial equator), precession will cause a change in position such that the declination at another time is given by:

$$\sin \delta' = \cos \delta \cos a \sin \theta + \sin \delta \cos \theta$$

where $a = \alpha + \xi$, and θ and ξ are determined by the distance the ecliptic pole has moved due to planetary precession and the distance the north celestial pole has moved due to luni-solar precession during the given time (Fig. 4). The values of these angles can be determined from the known rates and directions of the poles' motions. They have been tabulated for hundred years intervals from 4000 B.C. to A.D. 3000 (for equinox 1900) by Paul Neugebauer[9] who has also worked out the right ascensions and declinations for 310 bright stars at hundred years inter-

[7] ibid. p. 110.

[8] S. R. K. Glanville, *The Legacy of Egypt*, Oxford 1942, pl. 32.

[9] Paul V. Neugebauer, *Tafeln zur astronomischen Chronologie*. I. Sterntafeln. Leipzig 1912, pp. 8, 20.

vals from 4000 B.C. to A.D. 1900[10]. His tables and recent calculation by the same method show that one of the three stars in Orion's belt had

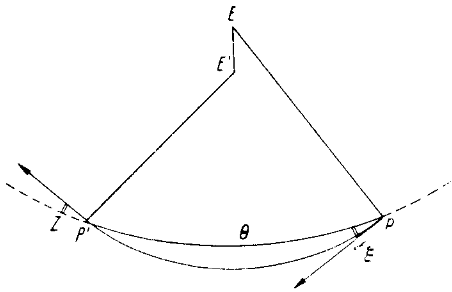

Fig. 4. Movements of Ecliptic Pole E to E' and Celestial Pole P to P', determining θ (arc of great circle passing through P and P') and ξ (angle between arc θ and instantaneous direction of pole motion at P)

a declination within 30° of $-15^1/_2°$ (2840 to 2480 B.C.). The positions of the stars during this period were:

Orionis Date	Declination	Orionis Declination	Orionis Declination
3000 B.C.	−16° 51′		
2900	−16° 20′	−16° 47′	
2800	−15° 49′	−16° 17′	−16° 33′
2700	−15° 17′	−15° 46′	−16° 05′
2600	−14° 45′	−15° 16′	−15° 33′
2500	−14° 17′	−14° 46′	−15° 04′
2400		−14° 16′	−14° 34′
2300			−14° 6′

This means that these three stars, whose importance to the Egyptians we have seen, passed once each day, at culmination directly over the southern shaft of the Great Pyramid at the time it was built.[11]

Thus considerations of Egyptian religion and modern astronomy combine to indicate that the "air shafts" of Cheops' Pyramid were actually intended as ways by which the soul of the deceased king might ascend to join the circumpolar stars and the god- constellation *Sȝḥ*.

It would seem likely that some other stars might pass in the same fashion over the opening of the shaft. It happens, however, that no other stars of comparable magnitude had declinations within 1°30′ of −14°30′ during that period.

[10] ibid. pp. 21–82.

[11] This culmination was, of course, rendered invisible by daylight during about half the year. It would have been visible about 2700 B.C. from late July to early January.