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AN INVESTIGATION INTO THE PURPOSE OF THE SOUTHERN SHAFT OF THE KING'S CHAMBER OF THE GREAT PYRAMID

Kyle Weyburne

Independent scholar M.Com.

E-mail: roboticafactory@gmail.com

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ABSTRACT

The main chamber of the Great Pyramid (the so-called 'King's Chamber') has two shaft inlets; one in the northern wall, the other directly opposite in the southern wall. They are the starting points of two long shafts which exit the pyramid's exterior. The purpose of these shafts has been disputed in scholarly literature with theories ranging from ventilation, to aesthetics, to stellar and solar targeting. This article investigates the southern shaft in particular, with the research presented here showing that it was possible for the sun's light to make it all the way in to the King's Chamber via this shaft. As a result, I favour solar targeting as the principal purpose for this shaft and present the hypothesis that this solar alignment played a role in the Heb Sed rites of King Khufu.

INTRODUCTION:

Theories on the Shafts

When the shafts in the King's Chamber first came to the attention of modern explorers, they could only see a short, horizontal section running five to six feet deep before sand blocked the view beyond, leading to speculation regarding their function. According to M. Maillet (Vyse II, 1840: 227) the southern shaft descended towards the bottom of the pyramid. Giovanni Caviglia (Vyse II, 1840: 158-160) argued that this shaft rose vertically before turning to connect to an unknown chamber. When Colonel Howard Vyse explored the pyramid in 1837, he cleared the southern shaft and found that it angled upwards in a fairly steady line. A stone had fallen into the shaft and according to his account (Vyse I, 1840: 286-287) "upon the removal of this

block the channel was completely open; 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." Vyse (I, 1840: 287) concluded that the purpose of the shafts were to ventilate the King's Chamber.

In 1872, Waynman Dixon and Dr. Grant investigated the second chamber in the pyramid (the so-called 'Queen's Chamber') and noticed a tiny gap in the wall. Figuring that this may hint at openings similar to those in the King's Chamber, they chipped away at the masonry and found a shaft about 21 x 21 cm (Gantenbrink, 1999). As with the other chamber, there was also one in the opposing wall, however, unlike those in the King's Chamber, these shafts did not reach the exterior of the pyramid. This discovery led to many abandoning Vyse's ventilation theory, although some such as Legon (1995) still support it, citing geometrical harmonies to support this conclusion. In a like manner, Dormion (2004) argued that aesthetics guided the arrangement of the shafts.

In 1964, Badawy (1964: 189-206) argued that the shafts of the King's Chamber had specific stellar targets. In the same year, Trimble (1964: 183-187) identified these targets, concluding that the southern shaft targeted the belt stars of Orion, while the northern shaft targeted α Draconus, the Pole star in the Old Kingdom era. According to Lehner (1997: 113) the purpose of the shafts were as a means of connecting the king to the heavens in order to assist with his ascension: "A symbolic function should also be attributed to the so-called 'air-shafts', which had nothing to do with conducting air. No other pyramid contains chambers and passages so high in the body of the masonry as Khufu's and so the builders provided the king's chamber with small model passages to allow the king's spirit to ascend to the stars". According to Spence (2003: 72) "[…] an increasing number of Egyptologists are now accepting that they [the shafts] may be aligned towards star culminations". Gantenbrink (1999) opposes this theory because the shafts do not provide direct site lines to their supposed target stars. Starting from the chamber, the shafts all carry the form of a short horizontal section, followed by an incline. Edwards (1981: 56) counters this by noting that the form of the shafts replicates the pattern typically found in pyramid design, wherein a horizontal section leads from the burial chamber to an inclined entrance shaft: "In this respect their design conforms with that of the regular entrance-corridors of pyramids, one of whose functions is also believed to have been to serve as a symbolical channel of approach to the circumpolar stars."

Solar versus Stellar Targeting

Trimble (1964, 183-187) concluded that elevation of the Pole star in Khufu's era matched the angle of the northern shaft at its culmination, while the belt stars of Orion aligned with the southern shaft. The specific star was Alnitak: once in every 24-hour period in Khufu's era, it aligned with this shaft at its culmnination. The elevation of the southern shaft used in Trimble's article was 44.5°. Gantenbrink's (1999) investigation of the shaft has revealed that the shaft's inclination is slightly steeper (45°), allowing for the identification of the potential target star: Alnitak at culmination carried an apparent elevation

of ~45° in the 26th century BC (Stellarium). While the circumpolar stars are known to have been important to the afterlife for kings of this era, issues exist regarding the importance of Alnitak in Dynasty 4. Alnitak belongs to the constellation which is presently called 'Orion', a set of stars that the Egyptians identified with the god Osiris from at least the Middle Kingdom, however, according to Neugebauer (1957: 82-83) it is unclear if these stars belonged to this god prior to then. Belmonte (2009: 311) argues that this identification is evidenced in the Pyramid Texts (specifically Utt. 882), however, Relke (2001: 255) details the problems with identifying Orion and Osiris: "The conflicting passages in the Pyramid Texts demonstrate simultaneous myths which equate Osiris and Orion and myths which do not." Furthermore, while Osiris is well-attested to in the Pyramid Texts of Dynasty 5 and 6 (e.g. Uts 436-442, 534, 577), it is unknown whether Osiris existed as early as Dynasty 4 (when the Great Pyramid was constructed). According to Shalomi-Hen (2015: 462) Osiris appears for the first time in offering formulae of high officials in the latter half of Dynasty 5. According to Baer (1960: 297) he first appears in the funerary temple of Djedkare-Isesi. According to Posener-Kriéger (1976: 52-55) he first appears in the funerary temple of Neferirkare. These temples belong to Dynasty 5. Osiris certainly came to be very important in the afterlife rites of the king, however, it is unclear if this relationship existed in Khufu's time.

The other potential astral target for the southern shaft was the sun. In 1881, Petrie (1883: 84) climbed the Great Pyramid so that he could determine the angle of the southern shaft using the sun's elevation. According to his account, the sun shone down this shaft at noon on two dates: 8 February and 2 November. Consulting NASA's Jet Propulsion Lab Horizons Interface (JPL), the sun was at 45.15° on both of these dates. Noon on these two dates were the only two times in the year when light from the sun entered the Great Pyramid, when for a few minutes it aligned with this shaft.

Badawy (1964: 189-206) proposed that the purpose of the southern shaft was to assist with the ascent of the king's soul to the sun; however, the proposed mechanism hinged on the belt stars and their association with Osiris (the difficulties of this proposition hinging on the existence of Osiris, as well as on his association with these stars in Dynasty 4). Conman (2007: 7) also argued that the southern shaft carried a solar purpose, linking the sun to the northern skies, thus functioning as a "magical irrigation system." According to Hawass (2015: 105) the function of the southern shaft is linked to the solar boats interred on the southern side of the pyramid.

What role Alnitak played in the afterlife rites of kings of Dynasty 4 is unclear, but the sun is known to have carried an important role. The ascension of the king to the solar barque is evidenced in the following Pyramid Texts (Mercer, 1952: 101, 196): "N. ascends to heaven, to thee, O Rē'" (Ut. 302, 461a); "Pure one, assume thy throne in the boat of Rē', that thou mayest sail the sky" (Ut. 513, 1171a-b). These Pyramid Texts belong to Dynasties 5 and 6, however Re worship may have reached new heights during Khufu's reign. According to Stadelmann (1985: 126) Khufu was the first king to be identified with Re, citing as evidence that his sons Djedefre and Khafre were the first kings to

carry the epithet 'son of Re', thus identifying their father with Re in Stadelmann's opinion. Further evidence linking Khufu to the sun god is provided by the four boat pits lying just outside and parallel to, the temenos walls. There are two on the south side and two on the east side, each facing a different cardinal point (Hassan VI, 1960: 66-68). Hawass (2015: 105) argued that the two southern boats were solar boats for the king so that he could "[…] accompany the god Re on his daily trips across the sky." According to Hassan (VI, 1960: 46) these two boats were "[…] a purely solar conception concerned entirely with the daily journey from east to west and the nightly journey from west to east." He interpreted the north and south facing boats on the east side of the pyramid as the night and day solar boats respectively. The presence of solar boat pits around Khufu's pyramid links this king to the sun, but it is likely that this link is much older than Dynasty 4. According to Emery (1939: 8) the Dynasty 1 boat pit of King Hor-aha was a solar boat, an identification which Hawass (1987: 38-39) considers to be a certainty.

The celestial target for the northern shaft was α Draconus which was also a key destination for the deceased king. The importance of the circumpolar stars ('imperishable stars') is made clear in the Pyramid Texts (Mercer, 1952: 148, 161, 202): "Thou [i.e. Osiris N.] who art very high among the stars, the imperishable stars, thou wilt not perish (go down), eternally" (Ut. 464; 878a-b); "Put thou N. as a prince among the spirits, the imperishable stars of the north of the sky" (Ut. 519; 1220a-b); "Mayest thou establish this N. in thee as an imperishable star" (Ut. 432; 782e). Even though the Pyramid Texts date to after Khufu's reign, many were composed earlier and according to Hassan (VI, 1960: 44-46) and Junker (1934: 53) this belief in a circumpolar destination for the deceased king predates Dynasty 4.

While the purpose of these shafts cannot be verified through any written documentation from the period, the fact that the four shafts emanating from the King's and Queen's Chambers carry three different angles when structural reasons cannot account for this, certainly suggests that it is possible that they were built to align to specific celestial targets. If so, a solar target (as opposed to the star Alnitak) for the southern shaft is more in keeping with the beliefs held by Old Kingdom Egyptians, as the sun is a recognised afterlife destination for the king. Evidence against a solar target is the fact that the sun aligned with this shaft on only two dates in each year, whereas Alnitak aligned with it once in every 24-hour period. Sakovich (2005: 1-2) argued that this required Khufu's funeral to occur on a pre-ordained date (i.e. on a date of solar alignment), effectively precluding the shaft's use in the funeral of the king. There is, however, another potential reason for the solar alignment; the king's Heb Sed rites.

Heb Sed

It is true that the date of Khufu's funeral could not be known in advance, however, the date of his Heb Sed could. Heb Sed is a ritual which was typically held once a king had ruled for 30 years and it enabled an ageing king to extend his reign. It is not known if Khufu reigned for that long, although not all kings waited for 30 years before celebrating this festival. King Osorkon

celebrated his Heb Sed in his 22nd year (Naville, 1892: 6) and King Akhenaten is thought to have celebrated his Heb Sed in his 6th year (Uphill, 1963: 124-125). According to the Turin papyrus Khufu ruled for just 23 years, however, many believe that this is insufficient time to construct his pyramid complex, consequently, Stadelmann (1985: 122) attributes Khufu a reign of 32 years. Reliefs of this festival have been recovered from Khufu's upper temple and causeway, suggesting that he did indeed celebrate a Sed festival or, if not, the complex was designed with this festival in mind. One block recovered from the causeway contains two Heb Sed scenes and references the name of the pyramid, leading Hassan (X, 1960: 23) to conclude that the scene was connected to the Great Pyramid. Sed festival scenes have also been recovered from the causeway, leading Hawass (1987: 122) to conclude that the Heb Sed played an important role in Khufu's pyramid complex.

According to Aldred (1968: 30): "In origin, the Sed Festival may have been a sublimation of a prehistoric rite whereby the divine king was slain when his powers began to wane […]. In historic times, however, this savage practice had been replaced by a magic ceremonial whereby the office of kingship was renewed." Consequently, a key aspect of Heb Sed was a mock funeral for the king in order to symbolize his death at the appointed time, followed by his 'rebirth' so that the revitalised the king could continue to rule (Uphill, 1965: 379). This event required a burial chamber equipped with a sarcophagus, making the obvious setting for this part of Khufu's ceremony to have been the King's Chamber. With this in mind, it is of interest to note where the shafts enter this chamber. It is a tall room, rising 5.84 m high, however, both shafts commence at a height of 91 cm above the floor, and, in their original form, both appear to have originally terminated at 107 cm (Petrie, 1883: 82; Gantenbrink, 1993). This is relatively low down in the chamber. If King Khufu stood in this chamber, the height of these shafts would correspond with his midriff. On two dates in the year the sun aligned with the southern shaft and since it was a direct communication with the chamber, it would funnel sunlight down its angled length. At its base the angle of the shaft turns horizontal, however, it could be considered that some aspect of the sun would be sent horizontally across the chamber. Speaking entirely hypothetically, if the king would have stood in front of this on a date of solar alignment, this communication between the sun and his body would in some way unite the king with the sun. Given the identification of Khufu with Re by Stadelmann, this could be interpreted as a powerful action.

Linking the deceased king (or a king feigning death such as in a Heb Sed ceremony) to the sun is consistent with the funerary requirements of some New Kingdom funerary texts. According to the Amduat and the Book of Caverns, it is the interaction between the sun and the deceased which revived the king in the afterworld (or, in the case of his Heb Sed, his revival as an earthly ruler). While these are much later compositions, Wente (1982: 175-176) and Baines (1990: 63) argued that parts of the Amduat date back as far as the Old Kingdom. A tantalizing clue to the age of such books is found in the 'Book of What is in the Underworld'; in the tomb of Tuthmosis I, a pyramid dominates the registers of the fifth hour, despite the New Kingdom kings opting for burials in tunnels within the Valley of the Kings. In the depiction,

the king as Osiris is buried within a pyramid and sealed within the 'Cavern of Sokar'. Resurrection of the king only occurred when the sun god penetrated this dark cavern. According to Hornung (1999: 37) the union of Osiris and the sun god occurred within this cavern. According to Lehner (1997: 30): "The exchange between light – the sun god – and darkness – the cavern of Sokar – allows resurrection to take place." Thus even in the New Kingdom, when pyramids were no longer the fashion for internment, the fifth hour of the Amduat depicted a pyramid accompanied by the belief that resurrection of the king could only occur if the sun god entered the chamber of the king. While it is speculative as to whether this belief existed in Khufu's time, the southern shaft of Khufu's pyramid potentially offered a means for the sun god to enter Khufu's burial chamber and interact with the body of the king.

The Heb Sed festival was designed not only to extend the rule of the king, but also to deify him. According to Nuzzolo (2015: 381-382) the decorative program of the southern corridor of Niuserra's sun temple focuses on the Sed festival of the king and a fragment within depicting Niuserra wearing the Atef crown and ram's horns evidences the deification of the king. This is a Dynasty 5 temple though, again making it unclear whether these beliefs were extant in Khufu's time, however, according to Nuzzolo (2015: 379-380) in Dynasty 4 the Sed festival focuses "[…] increasingly on the cult of the sun god as well as the solar traits of the pharaoh's rule. From Snefru on, the king claimed for himself the absolute power of the sun god, considering himself no longer, or better, not simply, an earthly manifestation of Horus but rather the real incarnation of Re. This belief was particularly stressed by Khufu through the great architectural project of Giza." If Nuzzolo is correct, then it makes the value of a solar alignment with the southern shaft of the King's Chamber clear, for it presented a potential means of linking King Khufu with Re as a means to facilitating the deification of the king during his Heb Sed.

The key reservation regarding the solar alignment theory is that the dates of alignment are fixed. This effectively precluded use during the king's funeral, however, it is my hypothesis that one of the dates of solar alignment was intended to mark the date of Khufu's Heb Sed funeral. In 1881, the sun aligned with the southern shaft of the Great Pyramid on 8 February and 2 November, however, the dates of alignment were different in the 26th century B.C. According to JPL the sun aligned on 8 February and 31 October (Gregorian). The exact dates for Heb Seds aren't known, but Tybi 1 was favoured in the New Kingdom (Piankoff, 1977: 42 n. 3; Hassan X, 1960: 34). It was not fixed to this date though. Ramses II for example, celebrated his 8th and 12th Heb Seds on Tybi 1, however, he celebrated his 10th and 11th Heb Seds on Tybi 17 (Mond & Myers, 1940: 163-164). One of the dates of solar alignment was 31 October, which is equivalent to Tybi 11. This is within the vicinity of when kings of the New Kingdom were celebrating their Heb Seds, adding weight to the hypothesis that the solar alignment may have carried a Heb Sed function.

If the southern shaft of the King's Chamber was designed to align with the sun in order to funnel sunlight into the Great Pyramid, then perhaps other pyramids of Dynasty 4 had similar shafts. His father is attributed the Bent

Pyramid at Dahshur. This pyramid has the regulation entry shaft low down on the northern side, but it also has a second shaft. Its dimensions are much bigger than those in Khufu's King's Chamber, creating a second entry 33.32 m up on the western side of the pyramid (Maragioglio & Rinaldi III, 1964: tav. 10). This shaft connected directly to the upper chamber, which Hussein (Williams, 1947: 303), Fakhry (1974: 97), and Monnier & Puchkov (2016: 21) argued was the burial chamber of King Snefru. This shaft emerges on the west side of this chamber inclining at an angle of 24.28°, however, 22 m from the exit its angle increases to 30.15° (Fakhry, 1959: 49). According to JPL the sun aligned with this shaft on 30 April and 15 August 2550 B.C. (Gregorian).

This shaft shares many features in common with Khufu's southern shaft: it aligned with the sun on two dates in the year; it links to a burial chamber; it kinks to prevent the direct solar effect; and, it is impractical to physically enter (as it is 33m up the western side). In combination, these two shafts carry enough similarities to suggest some form of compatibility. If, as proposed, Khufu's shaft was linked to his Heb Sed, then Snefru's western shaft might be as well. In other words, these solar alignments might have been designed so that they illuminated on the the dates of the respective Heb Seds of these two kings.

It is unknown if Khufu's successor 'Djedefre' had a such a shaft constructed within his pyramid, because the pyramid has been dismantled. Khafre succeeded him and while his pyramid doesn't have functioning shafts, it does have residual shafts in the burial chamber (Edwards, 1981: 55-56). Maragioglio and Rinaldi (V, 1966: 110) argued that these may have served as symbolic shafts. Menkaure's pyramid was next to be built and it has no shafts.

While these shafts are only to be found within pyramids built in the short span from Snefru to Khafre, their presence does suggest that they carried some importance for these kings. A similar fad occurred in the following Dynasty. Sun temples appeared at the start of Dynasty 5 with each of the first six monarchs of that Dynasty building one, then they stopped being built (Shalomi-Hen, 2015: 457).

The light of the sun entered the pyramid shafts of Snefru and Khufu on two dates in the year. Bends in these shafts prevented this light from reaching the burial chamber, however, since light emanates from the sun and travels away from it, it could not return to its host, thus it could be considered that some part of the sun was thereafter within these shafts and would continue onwards, following whatever twists and turns were presented to it. The aspect that potentially progressed onwards into the chambers might have been understood as the sun god's ba **(**which was disconnected from the sun in the Book of Caverns, and the Amduat). These two shafts thus created a link to a god that these kings hoped to join upon his solar barque. If the light of the sun did actually enter these chambers, it would have created a powerful spectacle that could easily have been interpreted as empowering the magic that was believed to be taking place at Heb Sed. This raises the question of whether sunlight could have entered these chambers.

The Southern Shaft of the Great Pyramid

The casing stones that originally sheathed the Great Pyramid have largely gone, leaving it unclear as to whether the King's Chamber shafts were originally open to the elements; however, Petrie was adamant that they were (1883: 52): "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." The southern shaft has kinks at its base which prevented the sun's light from entering the chamber. On the dates that the sun aligned, its light would have successfully passed down 22 blocks of the shaft's 26 blocks, unobstructed.[1] The remaining four blocks all carry different angles to these 22 blocks, thus preventing sunlight from reaching the base of the shaft. This however does not mean that sunlight did not enter the chamber.

It is evident that the southern shaft inlet has been expanded from its original 18 x 14 cm size (Gantenbrink, 1999). Nowadays, the horizontal section of the shaft is big enough for a small person to crawl into it (Edgar & Edgar, 1910: 249-250). The most likely cause of this disturbance is treasure hunting. Prior to this disturbance, it was possible to stare into the original 1.72 m long horizontal section of the shaft (Gantenbrink, 1993). If this portion of the shaft was bereft of anything, then that would be seen and consequently there would be no need to cut into it. Compounding things, Block 1 is made of granite, making it a difficult proposition to expand this shaft. Chiselling into such a small opening would have been a very difficult task which would only have gotten harder with every inch advanced. The northern shaft on the other hand, identical in all respects as far as could be determined from within the chamber, was left untouched. This suggests that there was a reason why the southern one came to the attention of the perpetrators and the northern shaft did not. The logical conclusion is that this shaft had something of value in it that was absent from the northern shaft.

The intrusion into this shaft probably began with a maximum of two workers chiseling out the hard granite stone above the shaft inlet to the point where a small adult could fit into it. As work progressed, the confined space necessitated a reduction to one worker. As he proceeded, he crawled into the shaft and eventually reached the second block. According to Gantenbrink (1993): "This segment of the shaft is nearly round in cross-section and seems to have been enlarged after its initial construction, probably by the same treasure hunters mentioned above." The worker was in very cramped confines by the time he reached Block 2. He then had to chisel upwards, with dust and chippings flying in his face. He continued working on the second block, enlarging the entire block. It seems likely that this kind of grueling work

[1] This is assuming that the shaft did not bend sideways when it was constructed (which it presently does). This issue is addressed later in the article. Note that there is a missing section of the shaft, however, according to Gantenbrink (1999) there were 26 blocks in all (i.e. one missing block). The blocks of the shaft are successively numbered from the chamber outwards by Gantenbrink and I shall follow his ordering.

would only be carried out for good reason, given the extreme difficulty of the operations.

This shaft was deformed before the first Western explorers entered the pyramid, so the intrusion likely dates to the Arab entry into the Great Pyramid. Calpih al-Mamun supposedly entered the upper sections of the pyramid for the first time since it was closed in Old Kingdom times, enticed by tales of hidden treasure within (Smyth, 1874: 83-89). The intruders were likely inspired to go to such efforts for a reason: namely, that something of value was within this shaft which was absent from the other one. In order to reach it, the treasure hunters presumably had to reach Block 2 and then remove something from that block. It would seem unlikely for this treasure to block the shaft (as all the other shafts are unblocked), so a likely form would be a lining which was of sufficient value to inspire these efforts, probably a precious metal.[2] While this is purely speculative, it is in keeping with the damage that has been inflicted on the first two blocks of this shaft. Lining the lower blocks of this shaft with metal would have had an intriguing effect. Blocks 5-26 are all inclined at 45°, but the last four blocks which connect to the chamber were constructed using different angles. Blocks 3 and 4 carry an inclination of 50.5°, Block 2 is inclined at 39.2° and Block 1 is horizontal (Gantenbrink, 1999). The blocks are approximately 1.7 m long and so the sun's light would have made it past Block 4 and ~0.5 m down Block 3 without any sheathing, on the two dates of alignment. Therefore, only Blocks 2 and 3 would have needed to have been sheathed in metal in order to enable the sun's light to reach the bottom of the inclined section of the shaft. This would have caused a glow to be visible within the shaft. Furthermore, if a reflective piece of metal was placed at the junction where Block 2 meets Block 1, at ~20°, then this would have resulted in a ray of sunlight passing horizontally across the room at noon on 31 October and 8 February. Alternatively, if such a mirror wasn't placed at the junction, then the lining could easily have been hidden from view so as not to attract treasure seekers' attention. Any potential metal sheathing could easily have been stopped before it reached the level of Block 1 and the delivery of the sun's glow would still have been visible from within the room, although it would have been confined to within the shaft. In this form, it would be unlikely that this effect would be detected for it would only occur for a few minutes on two dates in the year. To notice this, someone would have to stare into the shaft at the exact right moment, at a time when it wasn't blocked by sand. However, if an angled piece of polished metal was placed at the junction of Blocks 1 and 2, then this would catch the eye of treasure hunters and would inspire such efforts as have transpired.[3]

There is a further complication to the issue of whether the light of the sun could have made it all the way down the southern shaft of the King's Chamber. When Petrie (1883, 84) observed the sun shining down this shaft in 1881, he noticed that the shaft bent more than its width to the east, thus

[2] The Queen's Chamber shafts were blocked at the inlet and they do not make it all the way to the exterior, however, the shafts themselves had no blockages. Also, the most likely metal to have been used to line this shaft would be gold, since the Ancient Egyptians associated this metal with the sun (Traunecker, 2001: 44).

[3] The placement of a mirror at the base of the 30.15° section of Snefru's western shaft (angled at ~27°) could have been used to illuminate the upper chamber of the Bent Pyramid.

preventing sunlight making it all the way to the bottom of the shaft. Rudolf Gantenbrink (1993) explored this shaft with a robot (Upuaut-1) and discovered that sunlight was visible from Block 12 onwards (which is approximately mid-way up the shaft). Gantenbrink (1993) also noted that the inclination of the shaft was made with "[…] great exactitude and constancy […]" maintaining its angle of 45° from Block 5 all the way to the exterior. The acuracy employed in this shaft's inclination might suggest that a similar degree of accuracy would be attempted along its longitudinal axis. That it has not been is either due to the builders of the shaft, or to a disturbance post-construction. A plausible example of the latter might be an earthquake.

Egypt has suffered many quakes, the largest known occurred in 1303 AD. According to Badawy (1999: 127) "[…] in Cairo, almost all houses suffered some damage and many large public buildings collapsed. The earthquake caused panic, and women ran into the streets without their veils. Minarets of the mosques of Cairo were particularly affected. In Alexandria, many houses were ruined and killed a number of peoples. The lighthouse was shattered and its top collapsed."

Earthquakes had a serious effect on the Great Pyramid. According to Petrie (1883: 80) a quake was responsible for breaking every roofing beam of the King's Chamber and "[…] was enough to wreck the theoretical strength and stability of these chambers, and to make their downfall a mere question of time." To contort an entire pyramid requires a massive event and it was potentially the 1303 earthquake that did this. This earthquake reputedly toppled the legendary Lighthouse of Alexandria and flattened Cairo. According to the Egyptian Nuclear and Radiological Regulatory Authority (Morsy & Halim, 2015: 1195) this quake shook the Great Pyramid so violently that it also loosened its casing stones. Since this earthquake shook the pyramid so violently as to distort the King's Chamber and snap its granite roofing beams, as well as loosening its casing stones, then it is likely that the shafts were also affected. The longitudinal bend of the southern shaft potentially resulted from this earthquake, twisting the pyramid counter-clockwise. If so, then the injured portion would be expected to be the outer, upper section of the shaft, where there is less of the pyramid's bulk to constrain movement. Gantenbrink (1993) identifies Block 17 as the starting point of the eastward bend. This bend is subtle though, so the sun's light still makes it as far as Block 12 today; however, it presently bends more than its own 18 cm width, thus preventing sunlight from reaching the bottom of the shaft. If the northern shaft is likewise affected at a similar distance and in the opposite direction, then that would be a strong indicator that the pyramid was twisted by an earthquake (as opposed to the shaft being built with a bend).

Gantenbrink (1993) sent Upuaut-1 up the northern shaft and reported the following: "From this point on, the shaft seems to ascend at a constant angle. But we did discover a slight bend in the longitudinal axis […]. By comparing the relative positions of Upuaut-1's tow line, which ran parallel to the shaft, we were able to determine that this bend begins at the end of Block No. 20." The bend of the northern shaft of the King's Chamber starts at Block 20, rather than Block 17; however, this is to be expected because the King's Chamber is

offset 11 m south of the centre of the pyramid (Petrie, 1883: 83) and the northern shaft carries a lesser angle, thus requiring more blocks to reach an equivalent height. Since the southern shaft bends eastwards, this shaft would be expected to bend in the opposite direction if an earthquake had twisted the structure. Consulting Gantenbrink's CAD drawings confirms the westerly bend of this shaft.

The southern shaft is affected approximately 15 m from the exterior and 67 m up. The northern shaft is affected approximately 20 m from the exterior, but at the same height. This may indicate a weakness in the structure at this height that was exposed by an earthquake. The source of this weakness might be the terminal point of the King's Chamber structure. Petrie (1883: 187) estimated the apex of the relieving chambers above the King's Chamber to be 64.14 m above the pavement. Surmounting the uppermost chamber are two thick, gabled roofing stones, which may be doubled (as they are at the pyramid's entrance). Their total thickness is unknown, but adding the gabled roof takes the height of the King's Chamber structure close to the 67 m height where the two shafts bend. Therefore, it seems likely that the structure of the King's Chamber prevented torsional movement occurring lower down in the pyramid and only above this stabilising structure did the pyramid twist.

CONCLUSION

The proposed use of the southern shaft presented in this article is a speculative hypothesis, lacking any on site experimentation or written documentation; however it does provide a possible function for the southern shaft and an explanation for the desecrated state of its inlet. An earthquake may have twisted the Great Pyramid at the height that the structure of the King's Chamber ended. Correcting for this motion straightens the two King's Chamber shafts longitudinally. The southern shaft carries a steady incline of 45° except for the four blocks that connect the shaft to the King's Chamber. Blocks 1-4 carry various angles, thus preventing the sun's light from making it all the way down to the base of the shaft. The violation of this shaft by treasure hunters may have led to the removal of a reflective lining from Blocks 2 and 3. Furthermore, a mirror at the junction of Blocks 1 and 2 may have once existed. If such a mechanism had been in place, then in the 26th century B.C. sunlight would have been seen entering the King's Chamber at noon on 31 October and 8 February, crossing the room in a horizontal line. If the king had stood in front of the southern shaft inlet, sunlight would have connected with his midriff. Since solar alignments have set dates attached, then their purpose is unlikely to have been for Khufu's funeral, instead, they may have been designed for use during his Heb Sed ceremony, connecting the king to the deity that he wished to become the living incarnation of at the culmination of the festival proceedings.

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