Simultaneous Transit and Pyramid Alignments: Were the Egyptians' Errors in Their Stars or in Themselves?

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In a 2000 paper in the journal *Nature*, Kate Spence captured the imagination of the Egyptological world by using the circumpolar stars to calculate the date upon which the Great Pyramid was commenced and showing how the Egyptians might have used those stars to align the pyramids of the Old Kingdom with due north. [1] It has been nearly fifteen years since Spence published her theory. How well has it held up?

The Egyptians, Spence theorized, had used a method known as "simultaneous transit" to align the pyramids with due north. Spence noted that two bright northern stars, Kochab in the asterism we call the Little Dipper and Mizar in the Big Dipper, straddled the celestial pole in the pyramid age. In fact, in 2467 BC a chord drawn through them would have passed directly through the pole (Figure 1). An observer in 2467 BC could have held up a plumb line and waited for the two stars to transit behind it. At that moment, the line between the observers' pupil and the plumb line would have been due north.

For any two stars, however, this technique works perfectly only in one particular year. Owing to precession, a wobble in the Earth's orientation as it spins on its axis, the celestial pole moves relative to the stars. In the case of the simultaneous transit of Kochab and Mizar, this movement, projected onto the ground at Giza, amounts to 31 minutes of arc per century or about 3 minutes of arc per decade, about one twentieth of one degree. [2] (There are 60 arc minutes in one degree.) Therefore, if the Egyptians attempted to find due north using the technique ten years later in 2457 BC, their results would have been off by about 3 minutes of arc.

To Spence, however, this was an advantage. The effect of precession on the movement of Kochab and Mizar relative to the celestial pole could be used to provide the very date the Great Pyramid was started. To calculate that date, Spence used Josef Dorner's measurement of the casing on pyramid's west side. Dorner measured its azimuth, or clockwise angle off of due north, as -2.8 minutes (2.8 minutes west of north). [3] The two stars were 2.8 minutes of arc west of

north in 2476 BC. According to Spence's theory, that date, plus or minus five years or so, was the date the Great Pyramid was started. [4]

In theory, Spence's model can also be used to calculate the commencement date of the other Fourth Dynasty pyramids. Egypt's Fourth Dynasty was the pinnacle of its pyramid building age and included the building of all three pyramids at Giza (Khufu, Khafre and Menkaure) and the three pyramids of Snefru, Khufu's father, the first at Meidum, and the second and third, the "Bent" and the "Red," at Dahshur. Table 1 compares calculated dates for the commencement of these six pyramids using Spence's methodology with more traditional dates based on the work of von Beckerath and Stadelmann. Spence cites the von Beckerath and Stadelmann work in her paper as "currently accepted" chronologies. A plus sign in the table indicates that the pyramid is rotated clockwise from cardinal directions, a minus sign, counterclockwise.

Table 1: Analysis of the Application of Spence's Theory to Fourth Dynasty Pyramids

Pyramid	Spence's Tabulated Azimuths of Casings (Minutes of Arc)	Date of Commencement According to Spence's Theory [5]	Date of Commencement According to Spence's "Currently Accepted" Chronologies [6]	Difference in Years	Order of Commencement
Snefru-Meidum	-18.1	2525 BC	2598 BC	73	1
Snefru-Bent	-11.8	2505 BC	2583 BC	78	2
Snefru-Red	-8.7	2495 BC	2572 BC	77	3
Khufu	-2.8	2476 BC	2552 BC	76	4
Khafre	+6.0	2448 BC	2520 BC	72	5
Menkaure	+14.1	2422 BC	2487 BC	65	6

Spence's analysis does places the Fourth Dynasty pyramids in their correct order of commencement. However, on average, Spence's dates are 74 years later than those in the currently accepted chronologies. [7] Spence defends the difference stating that, "[E]xisting Egyptian chronologies of this period [which are] based primarily on cumulative reign lengths can only be considered accurate to about +/- 100 years."

Now, let's examine Spence's hypothesis in more detail by taking a closer look at the available data for these six pyramids (see table below).

For Meidum, Spence used the angle of the west side of the pyramid as recorded by Flinders Petrie, -18.1 minutes. [8] However, the base of the Meidum pyramid is not square. Petrie reported that north side is rotated -35.4 minutes with respect to cardinal points, the east side -20.6 minutes and the south side -23.6 minutes. The average error is -24.4 minutes. If the base of the Meidum pyramid was square, all four sides would share the same deviation from cardinal directions.

Spence used the data from Josef Dorner's survey at Dahshur for the Bent Pyramid. [9] Dorner reported -11.8 minutes as the angle of the west side of the Bent Pyramid. As is the case at Meidum, the base is not particularly square. Dorner found that its eastern side skews further counterclockwise than the west, running at an angle of -17.3 minutes. The north and south sides run -7.5 and -4.2 minutes respectively off cardinal points. The average error is -10.2 minutes.

Dorner also surveyed the Red Pyramid, but was only able to determine the azimuth of its eastern side, which he reported as -8.7 minutes. [10]

Spence used Dorner's survey at Giza for the angle of the Great Pyramid of Khufu, which was the best survey data available at that time. [11] Since then, however, we have new data derived from a survey by Lehner and Goodman. [12] The east side of the Great Pyramid runs at an angle of -3.4 minutes off due north, the west side -4.6 minutes, the north side -2.9 minutes and the south side -3.7 minutes for an average of -3.6 minutes. The base is nearly square.

For the Great Pyramid's neighbor, Khafre, Dorner's Giza survey data remains the best source. [13] The east and west sides of the Khafre pyramid are parallel and run at an angle of -6.0 minutes to due north. The north side runs at -5.2 minutes, and the south side -5.7 minutes. The average error of all four sides is -5.7 minutes. Like the Great Pyramid of Khufu, the base is nearly square.

In her analysis, Spence used the west side of the Khafre pyramid as measured by Dorner. However, Dorner reported the angle of the west side of the Khafre pyramid as -6.0 minutes of arc which would have placed the Khafre pyramid ahead of the Khufu pyramid in the order of construction. In her paper, Spence reporting its angle as +6.0 minutes, arguing that the Egyptians could have performed the Khafre alignment ceremony in the fall rather than the spring which would have had the effect of reversing the sign. As shown in Figure 2, changing the season of measurement from the spring to the fall inverts the positions of the Kochab and Mizar and inverts the sign of any structure aligned with the simultaneous transit of the two stars. Had Khafre been aligned in the spring rather than the fall, Spence argued, it would have had a positive angle of rotation. For that reason, Spence used an angle of +6.0 minutes in her analysis.

For Khafre's neighbor, Menkaure, Spence used Petrie's data. Petrie was not able to measure the angle of the pyramid's west side. Petrie reported the east side as running at +12.4 minutes relative to due north, the north side as +16.8 minutes off cardinal points and the south side, +13.0 minutes. The average for the three sides was +14.1 minutes. Spence used the average value in her analysis.

I have assembled the data for all six pyramids in Table 2. In order to evaluate Spence's hypothesis, I have tentatively adopted her proposed 74 year shift of the von Beckerath and Stadelmann chronologies. For the time between the commencements of the kings' reigns, I have used the von Beckerath and Stadelmann chronologies as well. In her paper, Spence did not do so, but adjusted the time between the commencements of kings' reigns to match her theory, arguing that the length of the reigns were not well established.

Table 2: Summary of Survey Data: Angles of Fourth Dynasty Pyramids

Pyramid	Date of Commencement According to "Currently Accepted" Chronologies Plus 74 Years [14]	N (Minutes)	E (Minutes)	S (Minutes	W (Minutes)	Average (Minutes)
Meidum	2522 BC	-35.4	-20.6	-23.6	-18.1	-24.4
Bent	2507 BC	-7.5	-17.3	-4.2	-11.8	-10.2
Red	2496 BC		-8.7			
Khufu	2476 BC	-2.9	-3.4	-3.7	-4.6	-3.6
Khafre	2444 BC	-5.2	-6	-5.7	-6	-5.7
Menkaure	2411 BC	16.8	12.4	13.0		14.1

I have plotted the data from Table 2 in Figure 3. At the top of Figure 3 we see the angles of the pyramids' sides as measured, and at the bottom, the angles with the orientation of the Khafre pyramid reversed as Spence has proposed. I believe the data neither confirms nor refutes Spence's hypothesis. It depends on sides of the pyramids deemed relevant, acceptance of a 70-odd year shift in timeline, and whether one accepts Spence's assertion that the Khafre pyramid was aligned in the fall rather than the spring.

However, there is other evidence that needs to be considered.

First, at the time Spence published her paper, the alignment of the Djedefre pyramid at Abu Roash was not known. Since Djedefre ruled between Khufu and Khafre, his pyramid should have had an alignment of between -3 and +6 minutes of arc. A subsequent survey of the pyramid showed it to have an average error of -49 minutes, plus or minus 3 minutes, a far different result than the Spence's theory predicted. [15]

Second, the alignment of descending passageways of the six pyramids does not match Spence's theory (Figure 4). We know from the Pyramid Texts that the Egyptians intended the descending passageways to be a portal to the circumpolar stars, so we would expect them to be aligned with the utmost care. [16] Indeed the alignment of the descending passageways is, in general, as good as or better than the casings. As I described in *How the Pyramid Builders May Have Found Their Due North*, it now appears that the Egyptians may have used the "pole star method" to align the passageways. [17] The pole star method tracks the movement of the pole star around the celestial pole in order to establish the direction of due north. If the Egyptians used the pole star method to align the passageways, why would they have used a different stellar method to align the casings?

Third, Spence proposed that the Egyptians invented the simultaneous transit method at or before the time the Meidum pyramid was commenced. At that time, the method was not particularly accurate; the Meidum pyramid is off due north by about a third of a degree. Then, according to the theory, the stars literally aligned for Khufu and Khafre. Their near perfect alignment was not a product of the ever increasing skill of the Fourth Dynasty surveyors, the theory implies, but largely a matter of fortuitous timing.

In contrast, the data clearly demonstrates that the Egyptians were becoming ever better surveyors as the Fourth Dynasty progressed. The base of the Meidum pyramid is not particularly square. But the Bent pyramid is better, and Khufu and Khafre are nearly perfect. For the last two, such precision may have been critical. There was not much room for error when it came to building enormous structures like Khufu or Khafre. If their bases were not level and square, the four sides of the pyramid may not have met at the top, or as Mark Lehner once put it, the pyramid builders might have literally missed the point.

Therein may lie the answer to the riddle: It may simply be that as the pyramid builders' skills improved, so did their ability to find true north using some other method than simultaneous transit, one not affected by stellar procession. We have several viable candidates, including the pole star and solar gnomon methods. [18]

If that is true, however, how do we account for the pyramid of Menkaure? The pyramid of Menkaure is not as well aligned with cardinal directions as Khufu and Khafre, nor is its base as square. Perhaps Menkaure, being a much smaller pyramid, simply did not require a precisely aligned base. [19] As Figure 5 demonstrates, there is a correlation between the size of a pyramid and its cardinal alignment. But another factor may be that after Khufu and Khafre the Egyptians' attention appeared to shift away from the pyramid itself and towards the temples and their endowments, which became larger and more elaborate. [20] With that shift in emphasis, they also may have become less concerned with precise pyramid alignments.

Spence's simultaneous transit theory was brilliantly conceived. However, I believe the available evidence, when viewed collectively, does not support it. Rather, it appears to me that the Egyptians' errors were not in their stars but in themselves.

Notes

[1] Spence 2000, 322.

[2] Rawlins and Pickering 2001, 699.

[3] Spence 2000, 320.

[4] To calculate a commencement date, we divide the azimuth of the pyramid by .31 to get a number in years which we add to 2467 BC. Thus, for the Great Pyramid, we divide -2.8 by .31 to get -9. We add this to 2467 BC to get a commencement date of 2476 BC.

[5] The dates of commencement here differ from Spence's tabulated dates of the king's accession by two years. She assumed, as I do here, that the pyramids at Meidum and Giza were started in the second year of the king's reign. Spence 2000, 320.

[6] Spence stated that she derived her "currently accepted" chronology by using "von Beckerath's chronology (lower estimates) with the exception of the length of Snofru's [Snefre's] reign and the dates of construction of his pyramids … which follow Stadelmann." Spence 2000, 320.

[7] Juan Antonio Belmonte has proposed that the Egyptians might have used Megrez and Phekda in the Big Dipper instead of Kochab and Mizar. Using those stars moves the commencement date for the Great Pyramid to approximately 2550 BC. Belmonte 2001, S11-S15.

[8] Petrie 1892, 6.

[9] Dorner 1986, 51.

[10] Dorner 1998, 23.

[11] Dorner 1981, 77.

[12] Dash 2012, 16.

[13] Dorner 1981, 80.

[14] To compute these dates, I started with the date for the commencement of the Great Pyramid using Spence's methodology as derived above, 2476 BC. Then, using lengths of time between reigns derived from the von Beckerath and Stadelmann chronologies (46 years for Snefru to Khufu, 32 years for Khufu to Khafre, and 33 years for Khafre to Menkaure) I then computed the dates for the start of the Meidum, Khafre and Menkaure pyramids. I assumed that the Bent Pyramid was started 15 years after Meidum and the Red, 11 years after the Bent.

[15] Belmonte et al 2009, 257. Belmonte also disputes this figure, stating that his own measurements with a GPS and a compass indicates that the pyramid is somewhat better aligned with cardinal points.

[16] Allen 2005, 10-12. Lehner 1997, 28.

[17] Dash 2013, 14.

[18] Dash 2013, 14. Dash 2015, 1-16.

[19] While the pyramid at Abu Roash was built at the time the Egyptians had the demonstrated ability to precisely align pyramids, it was much smaller than Khufu and Khafre and may also have not required a precisely aligned base.

[20] Lehner 1997, 135.

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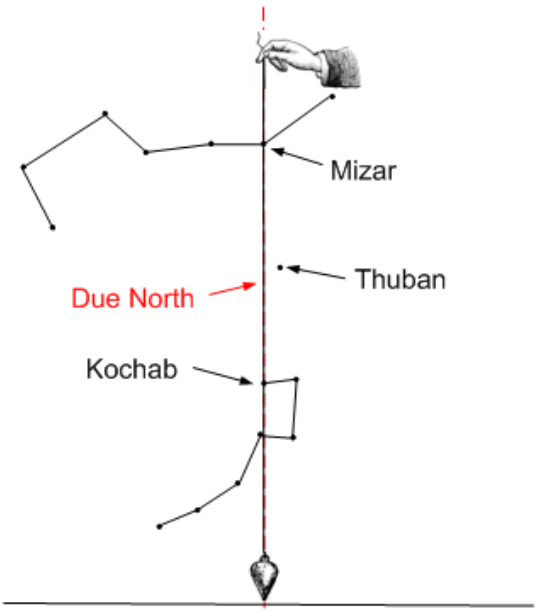
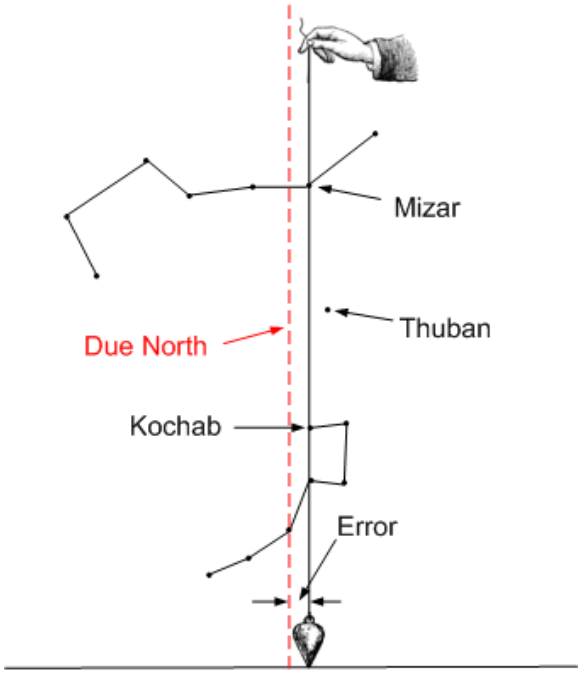
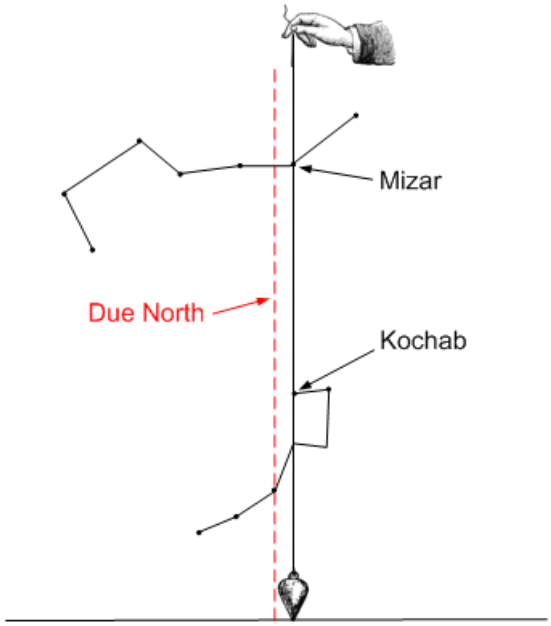


Alignment of Kochab and Mizar, 2467 BC

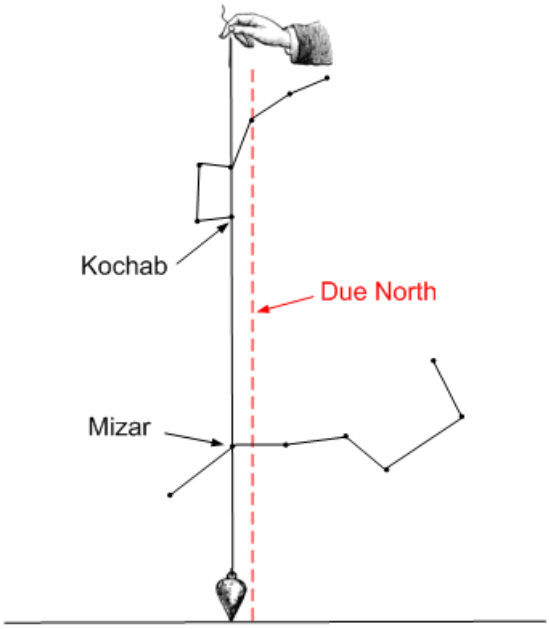


Alignment of Kochab and Mizar after 2467 BC

Figure 1: Spence's "Simultaneous Transit." An observer holding up a plumb line in 2467 BC would find Mizar and Kochab aligned with due north. After 2467 BC, the alignment progressively shifted east.



Mizar and Kochab Simultaneous Transit in the Spring at Giza After 2467 BC



Mizar and Kochab Simultaneous Transit in the Fall at Giza After 2467 BC

Figure 2: Change in alignment with the seasons. At Giza in the spring after 2467 BC, Mizar and and Kochab would align to the east of due north. A pyramid aligned using the two stars would be rotated clockwise from cardinal points. However, if the alignment ceremony took place in the fall, the two stars would align to the west of due north and the resulting pyramid would be rotated in the opposite direction.

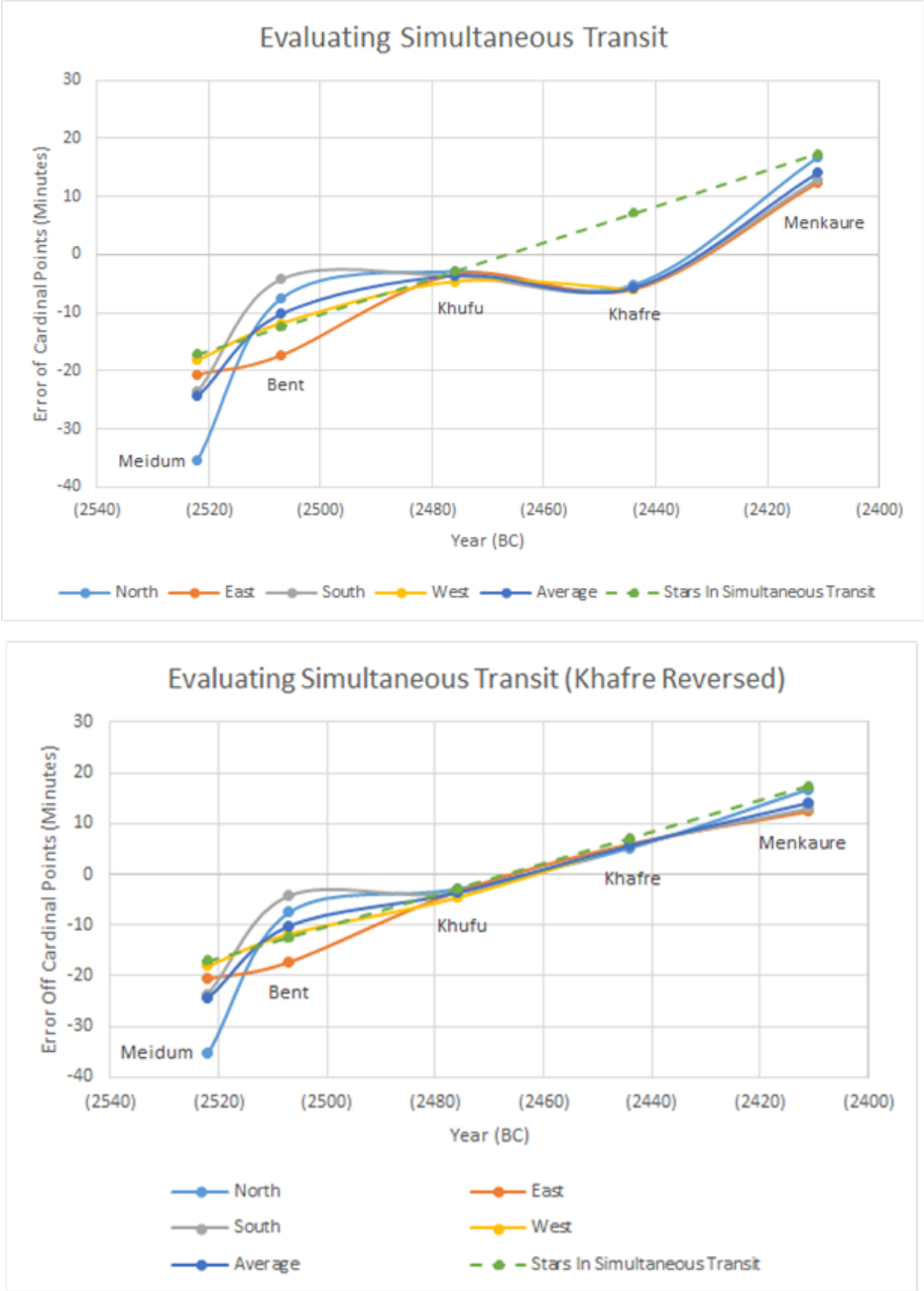


Figure 3: Evaluating Spence's theory. Plotted here are the alignments of five of the pyramids of the Fourth Dynasty. In accordance with Spence's theory, I have reversed the sign of the alignments for the Khafre pyramid in the lower plot. The Red pyramid, for which we have little data, is excluded.

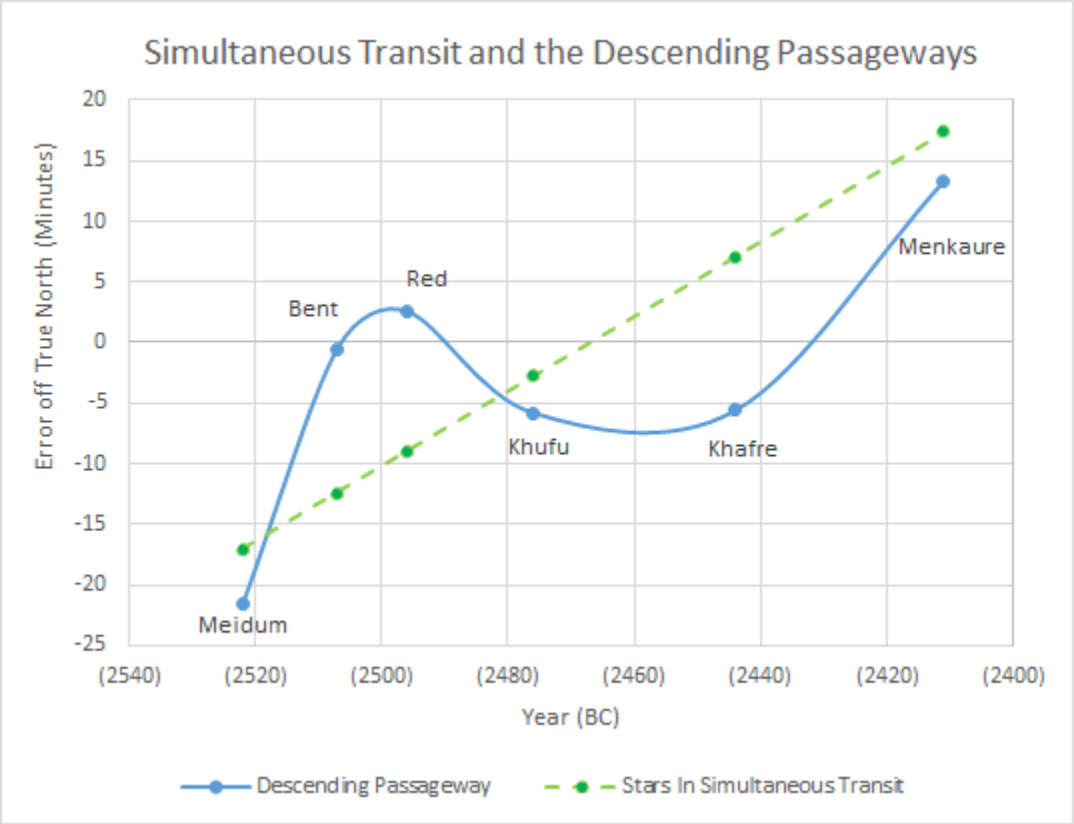


Figure 4; Simultaneous transit and the descending passageways. The alignments of the descending passageways of the Fourth Dynasty pyramids shown here do not match the simultaneous transit hypothesis. (On this graph, I have not reversed the sign of the Khafre pyramid.)

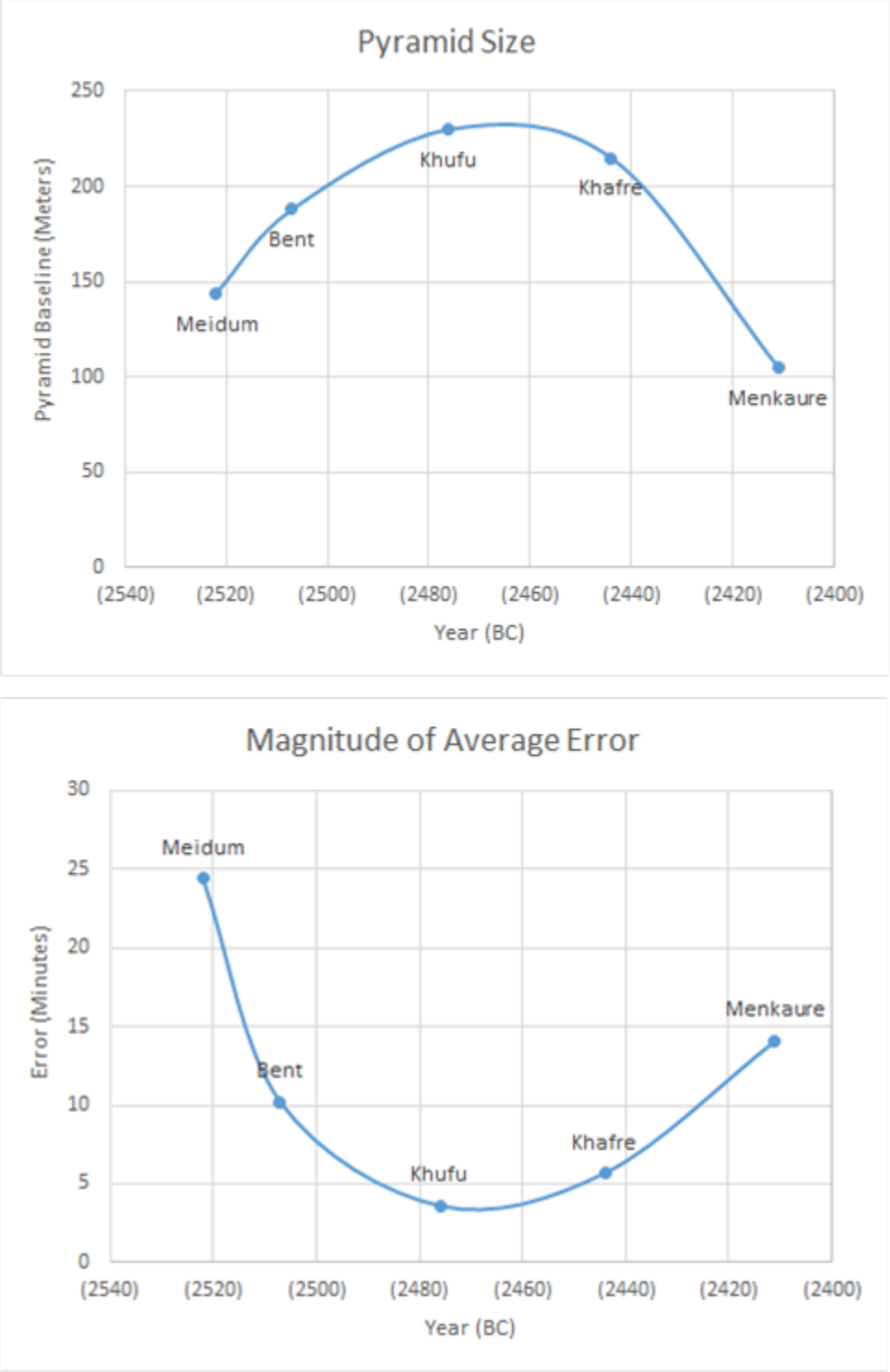


Figure 5: Alignments and size. In general, the larger the pyramid, the better it was aligned with due north.