How the Egyptians May Have Found Their True North

The Egyptians oriented the Great Pyramid to true north with astonishing accuracy. Here is how they might have done it.

By Glen Dash

The Great Pyramid is oriented to true north to an accuracy of two to four minutes of arc – one fifteenth to one thirtieth of one degree. That is a feat of engineering that would not be equaled for four thousand years.

In this article, I will review the bits evidence we have on how the Egyptians found true north from surviving inscriptions. I will then move forward in time to the sixteenth century when Tycho Brahe became the first person since the Egyptian Old Kingdom to match such precision. I will then present my case that the Egyptians may have used the same techniques as Tycho but four millennium before, and then test my hypothesis in the field.

The Writing on the Temple Walls

What evidence we have from the Egyptians comes mostly from the Ptolemaic Period two thousand years after the Pyramids were built. At Edfu, we find this inscription:

“I have grasped the stake along with the handle of the mallet. I take the measuring cord in the company of Seshat. I observe the progressive movement of the stars. My eye is now fixed upon Meskhet(yu). The god[dess] of time-keeping stands by me, in front of [her] merkhet. Then, I have established the four corner of your temple.” ¹

Seshat was a goddess of writing and time keeping, often depicted wearing an enigmatic crown (Figure 1). She also appears, mallet in hand, participating in “stretching the cord” ceremonies in

reliefs dating back to the First Dynasty. “Stretching the cord” was the name given to the rite that established the four corners of a temple or other structure. Meskhet(yu) was the Egyptian constellation “The Bull’s Foreleg,” equivalent to our Big Dipper. The merhket was a surveying device consisting of a vertical rope suspended from a wooden frame. Taken together, the clues suggest that the Egyptians (1) used the stars for alignment of important structures, particularly the stars of the Big Dipper, (2) found north, in part, by using a merhket, and (3) once they determined the proper alignment, laid boundaries by stretching the cord. Beyond that, the ancient record is virtually silent.

**Tycho’s True North**

Like the Egyptians before them, the Greeks, the Romans, and the Byzantines all needed to establish the meridian – the hypothetical line connecting due south and north – but they never achieved the accuracy of the Egyptians. By the end of the sixteenth century, ten minutes of arc was about the best surveyors could do.\(^2\) For most purposes that was sufficient. Ten minutes of arc, however, was not good enough to answer fundamental questions regarding the structure of the universe then being explored by Tycho Brahe (1546-1601) and other astronomers of his time. In the end Tycho did much better, establishing a meridian for his instruments to within 30 seconds of arc. He used his naked eye alone; optical instruments did not come into widespread use until the next century.

Among the many instruments Tycho built was the *Quadrans Volubilas Azimuthalis* or Revolving Azimuth Quadrant (Figure 2). He used the *Quadrans V.* to measure both the angle of astronomical objects above the horizon (their “elevation”) and their angle clockwise from true north (the “azimuth”). To use the *Quadrans V.*, Tycho stood on solid rings (T). He could rotate the entire apparatus on a pivot (E) to align its vertical plane with a particular celestial object. To determine its elevation, Tycho would raise or lower a device consisting of a fore sight (A) and a back sight (K) mounted on metal armature. The armature pivoted on A. Once he had aligned the sights with an object, Tycho could read its elevation off a graduated rim (P) and its azimuth from a circular scale R.

---

Similar devices had been made before, but Tycho achieved better accuracy because of the sights he used. Up until then, a typical sight used pinholes apertures (Figure 3). To let in sufficient light, especially at night, the apertures had to be considerably widened to avoid the effects of diffraction. Wider apertures meant greater error. To avoid this, Tycho invented, or perhaps re-invented, a method called parallel sighting. His sights employed four slits, two vertical and two horizontal, in both the fore sight and the back sight. Only when a star could be seen simultaneously through all four pair of openings was it truly aligned with the axis of the instrument, an alignment Tycho verified with slight head movements.

The instrument could also be used to identify the meridian. Here is how Tycho himself described the process:

"The zero point of the azimuths [true north], upon which depends the meridian line is determined with such care and accuracy that the observer will not err by a single minute. The meridian line we ourselves determined using a new method that is far more reliable than any one used before, namely with the aid of the pole star, when it is at greatest elongation from the meridian, on either side of it ... This is a simple an infallible method which I have devised. It was certainly worth the trouble, for where astronomical observations are concerned there is not much that can be done as long as the meridian line has not been very accurately determined."³

While Tycho’s description is terse, his method involved taking continuous readings of the azimuth of the pole star, Polaris, as it rotated around the celestial pole. Like all circumpolar stars, Polaris reaches its maximum east and west deviations from the meridian once a day, positions known as maximum elongations. The maximum east and west elongations are equal and opposite. Bisecting the angle they form defines the meridian.

Tycho and the Egyptians

Clearly, the Egyptians did not have the technology to build something like the *Quadrans V*. But could they have used the same methods Tycho used? Is it possible to design a mechanism that could do the same job and still be simple enough for the Egyptians to have built? I will attempt to do so below, but first I need to perform a critical field test: I need to demonstrate that the sights that Tycho and Hevelius designed can be adapted into a form that the Egyptians may have used but still be employed to measure the azimuth of a star with great accuracy.

Tycho used the *Quadrans V*. to map both the azimuth and elevation of stars. To define the meridian I need only to track a star’s azimuth, so I can eliminate the two horizontal slits since these are used only to find elevations. Next, I will adopt a modification of Tycho’s sights made by the Polish astronomer Johannes Hevelius (Figure 3, bottom). Instead of parallel slits in the fore sight, he used a single fixed post. Hevelius also replaced Tycho’s back sight with a dual vaned device slightly wider than the post.

In the fall of 2011, I set up the test site in Figure 4 to take the azimuth of Polaris. First, I placed Hevelius’ post/fore sight on a pole high enough in the air so I could use it to sight on Polaris while on the ground. Next I placed a dual vaned back sight on a bench far enough away from the pole so I could see Polaris and the post at the same time through the vanes of the back sight (Figure 5). The post/fore sight consisted of a 0.25 inch (6.35 mm) diameter rod mounted atop a pole on a second story porch. I used two carpenter squares set 0.625 inch (15.875 mm) apart for the back sight and placed these on the wooden bench. I leveled the bench using a spirit level and set it at right angles from the pole using a third carpenter’s square.

On the night of October 10, 2011, I tested the accuracy of the arrangement. I moved the back sight along the bench until both Polaris and the post were visible through the opening formed by the vertical uprights of the back sight’s carpenter squares. I then moved my head slightly until Polaris was occluded by the post. Holding my head still I then centered the post in the back sight by moving the back sight slightly to the left and right. Once that was done, I moved my head from side to side just slightly until I could just see Polaris emerging from behind either side of the post. The angle formed by the center of the back sight and the post now matched the azimuth of Polaris. I demonstrate the process in Figure 6.
At the time of my measurement, Polaris was at an azimuth of 55 minutes and zero seconds. I measured the angle formed between the center of the back sight and post/fore sight. It was 55 minutes and 28 seconds (Figure 7). I had correctly measured the azimuth of Polaris to better than 30 seconds of arc, just as Tycho had done. I repeated the measurement twice more that night with errors of 8 and 43 seconds of arc respectively.

**An Egyptian Observatory**

While the ability to measure the azimuth of a star accurately is essential, in order to establish the meridian I need to measure the azimuth of the pole star at its maximum eastern and western elongations. I would then need to bisect the angle formed.

To do that, I propose using the simple observatory of Figure 8. A merkhet-like device at the northern end of the observatory replaces the rod and post arrangement I previously used. The merkhet can be used to sight more stars than just the pole star, which would be useful, and is self-plumbing. The bench supporting the back sight is curved to maintain a constant distance of 10 meters from the point where the plumb bob meets its base. This makes it easier to bisect angles. To make observations, I would use the merkhet’s vertical string to occult the star. Once a star was occulted, I would center it between the vanes of the back sight. Eventually, the star would reach its maximum east and west elongations. I would record these by marking the location of the center of the back sight directly on the bench. Once that was done, I would bisect the angle formed by the two elongations and the place where the merkhet’s plumb bob met its base by conventional means. The bisecting line would be the meridian.

I believe there is nothing in the above that the Egyptians could not have done as well.

I used Polaris, but owing to precession (the periodic wobble of the Earth’s axis over time), the Egyptians would have used Thuban, in the constellation Draco, as their pole star. If Thuban proved to dim, the next best choices would have been circumpolar stars Mizar or Alioth in the Big Dipper, just as the inscriptions suggested.
The Crown of Seshat

Ali Guerbabi, the former director of the site Museum of Timgad in Algeria, first made the observation that the crown of Seshat may not have been merely symbolic, but might have represented something real.\(^4\) He thought it might be a survey instrument. While preparing this paper, I noticed that the proposed observatory in Figure 8, when viewed from above, also resembled the crown. It is possible, therefore, that the crown may indeed represent something real; it may be a schematic representation of such an observatory, complete with its dual vaned back sight.

A Summary: The Egyptians, Tycho and True North

It took four thousand years for Tycho to do what the Egyptians had done. We do not know how the Egyptians did it, but Tycho did it by parallel sighting. I know no other way to achieve such accuracy with simple tools and the naked eye. Therefore it appears to me that the Egyptians, four millennia earlier, must have happened upon the same technique. Here I have demonstrated that a simple parallel sighting arrangement using John Helevius’ modifications of Tycho’s sights can measure the azimuth of a star to accuracy better than 30 seconds of arc. All that remains to be done is to build the observatory as the Egyptians might have done, take the elongations, bisect them and confirm the meridian. I am hoping to do that in the coming seasons.

\(^4\) J. Belmonte, M. Polo and N. Miranda (2009: 207)
Figure 1: The Pharaoh along with the Goddess Seshat is shown performing the “Stretching the Cord Ceremony” in this relief from the Red Chapel at Karnak (18th Dynasty). Seshat wears a star emblazoned crown. The merkhet was a surveying tool. (Photos by J. Belmonte)
Figure 2: Tycho’s *Quadrans Volubilas Azimuthalis* or Revolving Azimuth Quadrant.
Figure 3: The Evolution of sights. The key to Tycho’s success were the sights he used. Helevius improved these further.
Figure 4: Shooting Polaris. To measure the azimuth of Polaris the author set a post atop a rod on a second story porch and sighted Polaris using a dual vaned back sight slid along a wooden bench.
Figure 5: Close up of the dual vaned back sight and bench. The back sight can be slipped to the left or right along the bench.
Figure 6: Using the post and back sight. At the top, the author is shown aligning the back sight on the rod and post. At bottom, the view through the back sight during the daytime.
Figure 7: Results of our measurements. After Polaris is sighted through the back sight, a total station is used to measure their relative positions. The coordinates are in meters (N-North, E-East and Z=Elevation). The east-west axis has been exaggerated for illustrative purposes.
Figure 8: An Egyptian Observatory? To establish the meridian, the set up shown can be used. A circumpolar star at maximum elongation is occluded by the rope suspended from a giant merkhet. The back sight is aligned with both by sliding it along a curved bench. Bisecting the angle formed from the maximum elongations results in the meridian.