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AN EYE FOR A WHAT?

By DAMON KNIGHT

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WILLY LEY EXPOSES THE GREAT PYRAMID "MYSTERY"

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THE IGNOBLE SAVAGES

By EVELYN E. SMITH

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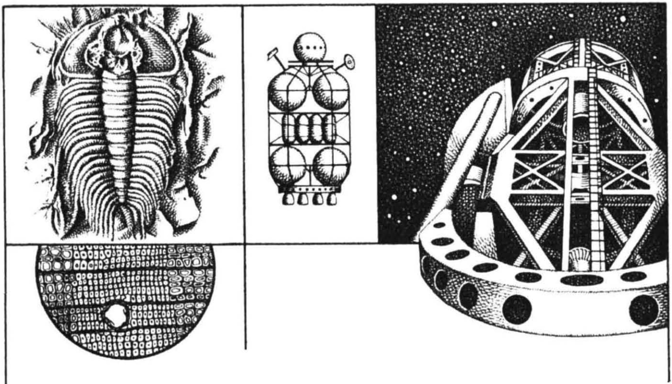
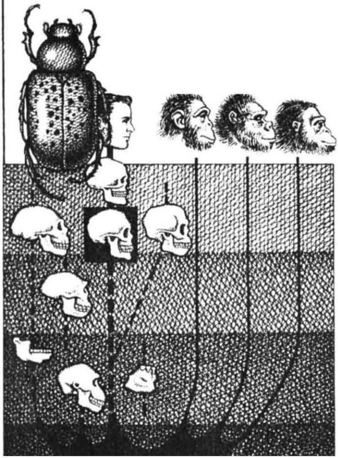
AND OTHER STORIES



for your information

By WILLY LEY

The Great Pyramid The Golden Section and PI



TO REASSURE all those readers who, when reading the above title, muttered to themselves that these three things have absolutely nothing to do with each other, I wish to state in this very first sentence that I agree with them. Of course neither the "golden section" nor *pi* is hidden in the structure which an ardent and effusive admirer once called the Miracle in Stone, using the word "miracle" in its literal religious meaning. But it is an interesting story how all the multitudinous misunderstandings surrounding the Great Pyramid originated.

That the pyramid of King Khufu was a major engineering and organizational accomplishment is something that does not need to be stressed.

It is not only astonishing that a structure of such size was built as early as it was; it is also astonishing how well it was built. As a matter of fact, Khufu's pyramid is of better workmanship than the later pyramids built on the same plateau, the so-called pyramid plateau of Giza, about six miles to the west of Cairo. Since Khufu was the first to build a pyramid in this particular locality, the whole plateau was originally named after him. It was called *Akhet Khufu*, or "Khufu's Horizon."

WHY Khufu picked this particular locality for his pyramid is not known. That is, we don't know of any inscription saying that Pharaoh decreed this site because his fellow gods had told him to begin his soul-voyage after death from this place. But we can think of a number of eminently practical reasons why he chose this spot.

To begin with, he could see it from his summer palace and watch the actual work going on. Secondly, the location of the building site was such that, when the annual Nile flood occurred, the blocks of stone could be floated on rafts to the foot of the growing structure. Finally, most egyptologists (and especially the Egyptian egyptologists) believe that Khufu's pyramid hides an outcropping of natural rock which obviously saved that much work in the erection of a virtually solid structure.

Even so, 2,300,000 blocks of stone went into the pyramid, averaging 2½ tons in weight, with a few that must weigh about 15 tons each. The rock was quarried nearby. Professor Selim Hassan found some ancient quarries within easy walking distance of the pyramid.

Originally the pyramid had an outer casing of white limestone — Greek writers who saw it blinding white under the desert sun assumed that it was white limestone all the way through — which is now gone. Not completely gone, though; it merely is no longer a part of Khufu's pyramid, but forms portions of still-standing mosques.

Without its casing, the pyramid is 450 feet tall. We can't tell precisely how high it was originally.

The white limestone came from Turah, somewhat farther south and on the other side of the river, involving transportation over 14 miles of water. Some of the granite used in the interior came from Aswan, a good distance up-river, but again with the possibility of water transport.

It was the height of the structure which is responsible for its name. The Egyptians called this height *pyr-em-us.* The Greeks adapted the term to their tongue

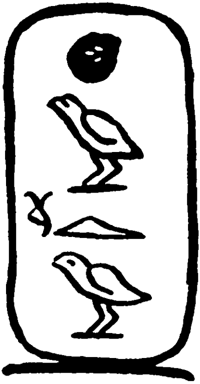


Fig. 1.
King Khufu's name: the line around it, called cartouche, means it is a king's name

by pronouncing it *pyramis* and using it as a designation for that particular shape. Herodotus coined a plural, *pyramides,* from which, at a much later date, the current singular "pyramid" was derived.

Since we are on the subject of names, I am sorry to report that we don't really know how the name of the king was pronounced. The written form (Fig. 1) transliterates as *Hwfw* which, in order to be able to say it at all, is pronounced Khufu. Cheops (the "ch" should also be sounded as "kh") is the Greek form used by Herodotus.

HERODOTUS, incidentally, seems to have been the first who told stories about the pyramid which do not strictly jibe with the truth.

"One of the most frequently repeated stories," to quote Prof. Hassan Selim, from an article in the Egyptian monthly *The Scribe,* February, 1956, "is that in order to build the pyramid, Khufu closed the temples and enslaved the whole population to work as slave-laborers on its construction. This story has been going the rounds since the middle of the Fifth Century B. C., when the Greek traveler and historian Herodotus visited Egypt and evidently fell into the hands of a typical dragoman, who, like his modern descendants, thought that a few sensational stories would earn him a bigger tip from the gullible stranger."

They probably did, but because more than a score of centuries had gone by since the actual work, the Egyptian may easily have believed his own stories.

A dozen centuries after Herodotus, other travelers came and saw the pyramids. Apparently no stories were told any more, and though the travelers probably saw examples of hieroglyphic writing, there was nobody on Earth then who could read it. Consequently they wondered about the nature and the purpose of these structures.

Christian travelers, remembering their Bible, theorized that these must have been the giant storehouses for grain which Joseph had built to combat the forthcoming seven-year famine. Moslem philosophers remembered the older writings, too, but evolved a different explanation. There may have been kings not mentioned in these writings and the prophets of these kings must have told them about the future coming of the deluge. The kings then ordered the pyramids built as refuges from the coming flood.

Some less learned people reasoned that anything so massive must guard great wealth in gold and jewels, and they drew practical conclusions from their opinion, sometimes with success.

All these speculations dealt with pyramids in general, the pyramids of Egypt which extend over an area of 40 miles from north to south along the Nile (ten times as much if you include a few far to the south near Thebes and Edfu). The speculations of the last century are restricted to just one pyramid, that of Khufu.

The one who started it may have been, in all innocence, the famous astronomer Sir William Herschel. In his time, nobody knew just how old the pyramids were. The only thing that was certain was that they had already been old in the time of Herodotus. Herschel, learning that the entrance to the pyramid of Khufu formed a rather steep incline, may have been reminded of his telescopes and he wondered which star one might see if one were standing on the bottom of the entrance.

Some rather tedious calculations provided an answer. Looking through that shaft, an observer would have seen the star *alpha Draconis,* if the year were 2160 B. C. Herschel then stated that the pyramid may have been built in that year.

We now know that it is much older.

BUT Herschel's attempt to date the building of the pyramid on astronomical grounds took hold — long after his death.

It was in 1859 that John Taylor, a London publisher and bookdealer, published a book which he had written himself. It bore the title *The Great Pyramid, Why was it built and Who built it?* His conclusion was that the pyramid had been built for the purpose of embodying a few important measurements. If Taylor had been an American, he might have said that it was the Egyptian equivalent of the Bureau of Standards, with the additional twist that all the standards are "classified information" not meant for the average dumb citizen.

In the course of his romancing, John Taylor discovered that the Egyptians must have used the same units of measurement as the English — or at least the more important of these units — and he succeeded in finding a unit which had been lost. In England at that time, a Quarter was used as a measurement for wheat. Taylor said, "A quarter of what?" and found the answer: The original "whole," four Quarters of wheat, was the "so-called" sarcophagus of the pharaoh.

Taylor also found that the height of the pyramid (which he overestimated by a few feet) was 1/270,000 of the circumference of the Earth. Here one can only say, "Why not?" for the height of the pyramid obviously must be some fraction of the circumference (or of the diameter) of the Earth.

Taylor was willing to admit that a few such things could be coincidences. To feel sure that it was planned, he looked for something which could not be a coincidence — or so he thought — and he found one, too. The square of the height of the pyramid, compared to the area of one of its triangular faces, demonstrated the "golden section."

That "golden section" had been around ever since the days of Euclid and had at irregular intervals taken hold of somebody's imagination. (At present, hardly anyone pays any attention to it.)

Let's first see what the term means (Fig. 2).

We have here a distance *AB* which is to be divided according to the golden section. To do so, we erect a vertical line in *B* which is precisely half as long as *AB*. The rest of the construction can be read off the diagram. The result is that the distance called the *minor* has the same proportion to the *major* as the *major* has to the total, namely *AB*. And if we now subtract the *minor* from the *major*, we have divided the *major* according to the golden section.

THE golden section was publicized for the first time by an Italian, Luca Pacioli, who may be the inventor of double-entry bookkeeping; at any rate, this method appears in print for the first time in one of his books. After having produced this boon for tax collectors and merchants, he intended to bestow a similar boon to artists with a book called *De Divina Proportione,* published in 1509 with illustrations by his friend Leonardo da Vinci.

Pacioli tried to show — and succeeded to a good extent — that most of the things we consider "beautiful" are constructed in accordance with the golden section when broken down into measurements. The numerical relationship of the golden section is 5 to 8 and, for centuries, all books did correspond to it. European books still do, at least more often than American books. The only book in my library which is of American origin and which shows that proportion is the *World Almanac.*

The next time the golden section was consciously "rediscovered" by the artists, or more precisely by the theorists of art, was around the middle of the nineteenth century, just the time in which John Taylor wrote. It cannot be said that his book was a success and it probably would have been forgotten completely if it had not been for Charles Piazzi Smyth, at that time Astronomer Royal for Scotland.

Smyth was the son of an admiral and he happened to be born in Italy. His godfather at the christening was Father Giuseppe Piazzi, the discoverer of the asteroid Ceres, the first asteroid to be found. Father Piazzi said then that he hoped that the child would become an astronomer.

Charles Piazzi Smyth did become an astronomer and, as an astronomer, he made important contributions to spectroscopy, then a very new science. He also deserves much credit for advocating an innovation which now seems obvious to us — building observatories on high mountains.

At the age of forty, Smyth came across John Taylor's book and became enchanted with it. Thinking and dreaming about it, he quickly convinced himself that Taylor had barely scratched the surface. He thought and calculated and worked and, in 1864, he wrote a 600-page book called *Our Inheritance in the Great Pyramid.*

It was a great success and its awed readers learned that the main item in the plan for the Great Pyramid had been nothing less than the squaring of the circle. Smyth said that the bottom

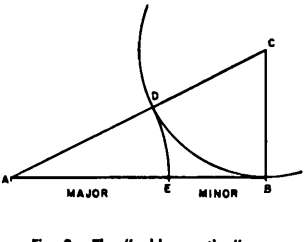


Fig. 2. The "golden section"

square of the pyramid represented — or, rather, was equal to — the circumference of a circle drawn with the height of the pyramid as its radius.

WHOEVER read this with a critical or just an open eye should have stopped right there. Maybe the base of the pyramid measured 3055.24 feet, as Prof. Smyth said, but how about the height? The outer casing and with it the point of the pyramid were missing. Therefore the height could not be measured directly. Of course if the casing had been there, one could have measured the slope angle and calculated the height from that.

The slope angle must have been near 52°, so Smyth said that it originally was 51° 51′ 14.3″ which produced a height of 486.256 feet. Therefore the ratio of height to circumference corresponded to two *pi.* Insisting that this could not be a coincidence and apparently unaware of the fact that he himself had not *found* the figure but *put it in,* Smyth went on to other discoveries.

At the base, one side of the pyramid measured 763.81 feet. The Egyptians naturally had not used feet as a unit of measurement; it must have been something else. Smyth divided these 763.81 feet by 365.2422 and got a unit he called the "pyramid meter." Why this figure? Obviously the builders of the pyramid had wanted to express the number of days in the year by the base line.

Dividing the pyramid meter into 25 equal parts, Smyth obtained the pyramid inch, which, by a strange coincidence, differed from the English inch by just 1/1000th of an inch. Obviously the English still used the pyramid inch, but had not kept its length accurately through the millennia. It had shrunk by 1/10th of one per cent.

Having the "pyramid meter" and the "pyramid inch," Smyth really got going.

Multiply the pyramid inch by 10^7 and you have the length of the polar axis of the Earth.

Multiply the pyramid inch by the height of the pyramid (in pyramid inches, of course) and then multiply that figure by 10^9 and you get the distance from the Earth to the Sun. (The result is 91.84 million miles, which is neither perihelion nor aphelion nor mean distance.)

Express the cubic content of the pyramid in cubic inches and you have the total number of all people that have lived on Earth since the Creation.

AS FOR the so-called sarcophagus, it was not only the original standard for volumetric measurements, according to

Smyth. It was more. Its volume, expressed in cubic pyramid meters, was precisely 5.7, which looks like a wrong figure until you realize that this is the specific gravity of the Earth as a whole! (Actually the density of the Earth is 5.52.)

One reader, by profession an engineer, wrote later that Smyth's treatise cost him the better part of a night and that it had the result that he "did not fall asleep in my bed but in a medley of endless decimals, triangles and circles, complicated by polar diameters and astronomical distances; dealing with empty granite sarcophagi and pharaohs with mile-long measuring rods marching through space with the luminous eyes of prophets."

He realized that Smyth had "found" his "cosmic figures" in the pyramid by putting them in in the first place. But he also said that he had the faint feeling that something still needed to be explained.

It was explained several decades later by the egyptologist Ludwig Borchardt, who approached the whole problem from the opposite direction. He asked just what unit the Egyptians had actually used in building. Moreover, he wanted to know just how far advanced their mathematics had been.

As for the unit of measurement, he found that they used the ell. There was a minor complication in that it seemed that they had used two different kinds of ells. One had a length of seven palms, the other of six palms. Although the six-palm ell corresponds better to reality (an ell is the length from the elbow to the tip of the longest finger), the seven-palm ell was used for construction, at least for large buildings.

In our measurement, the "royal ell" of seven palms is a little less than 21 inches. Borchardt used 525 millimeters as an approximation. Then the palm would be 75 millimeters or just about three inches. Each palm, in turn, was divided into four fingers, which would measure 19 millimeters each if the figure for the royal ell of 525 millimeters is accepted. At any event, the ell had seven palms or 28 "fingers."

As regards Egyptian arithmetic, we know that they could handle simple fractions like ½, ⅓, ¼, etc., and fractions like ¾ (namely 1 minus ¼) or ⅔ (1 minus ⅓). When it comes to pyramids, we have a few examples in the famous *Papyrus Rhind* which, while old, is probably a good deal younger than the pyramid.

EXAMPLE No. 56 in the *Papyrus Rhind* requested the pupil to calculate the slope of a pyramid with a base length of

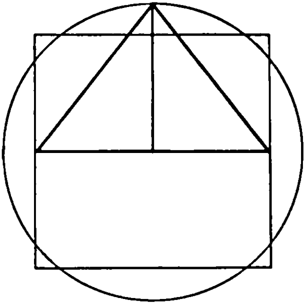


Fig. 3.

Piazzi Smyth's construction of squaring the circle with the aid of the Great Pyramid

360 ells and a height of 250 ells. A modern high school boy would reach for the logarithm table and come up (unless he made a mistake) with the answer 54° 14′ 46″. The Egyptian advanced pupil answered 5 1/25 palms.

Example No. 58 said that the base length was 140 ells and the height 93⅓ ells. The answer was 5¼ palms.

And example No. 59 (no doubt dealing with a backyard pyramid) gave 12 ells as the length of the base line and 8 ells as the height. The answer was also 5¼ palms.

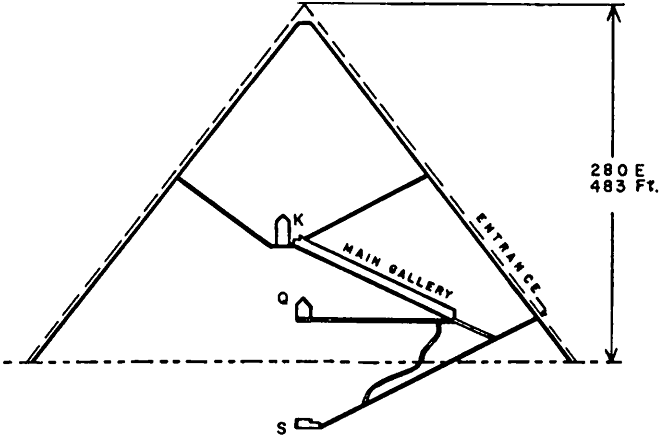


Fig. 4.

Cross section of Khufu's pyramid. S means an abandoned burial chamber (unfinished), Q is the so-called Queen's chamber, never used, K the King's chamber. The two shafts to the King's chamber were for ventilation

What do these answers mean?

The answer is given in Fig. 5. The answer meant that the slope of the pyramid was so many palms from a vertical line one ell in height. That this is correct is proved by the fact that measuring triangles for the use of builders and masons have been found which corresponded to slopes of 5, 5¼, etc., palms, all rather awkward angles if expressed in degrees and minutes of arc.

The slope of the Great Pyramid was quite close to 52°. For lack of the casing, one could not be any more precise than that. A slope of 5½ palms produces an angle of 51° 50.6′. And that would have made the pyramid 280 ells high, a neat, even figure —in Egyptian measurements, that is.

Now remember that John Taylor had proclaimed that the pyramid represented the golden section. Prof. Smyth had proclaimed that it represented *pi*. Since it cannot possibly do both, Borchardt calculated what the respective angles would have to be and how the measurements would have come out in Egyptian ells. The result surprised everybody. You find it clearly demonstrated in this table:

	SLOPE		
	for *pi*	for 5½ palms	golden section
slope angle	51° 51.2′	51° 50.6′	51° 49.6′
slope (Egyptian)	4.4979 P.	5.5000 P.	5.5032 P.
base line for 280 ells height	439.82 E.	440 E.	440.24 E.

SMALL wonder that people were led astray if the *pi* slope, the golden section slope and the simple Egyptian slope were practically the same. They are so much alike that it is impossible to distinguish them on a drawing of anything like publishable size.

That they did not "intend" to build a *pi* slope is also clear from the *Papyrus Rhind*, where the ratio we now call *pi* appears in examples No. 41, 48 and 50 in the form that 8/9th of the diameter of a circle is the side of a square of equal area. In our notation, this makes *pi* equal to 3.1604, which is too large. If they had tried for the *pi* slope, it would have been a different pyramid, considering their idea of the value of *pi.* There is no way of saying whether they knew the golden section, but it is not even remotely likely.

We are left then with the realization that Khufu's builders were extremely skilled workers, but that they did not try to hide any cosmic secrets. And where did they acquire their skill? Well, while the Great Pyramid is the biggest and one of the oldest pyramids, there had been considerable practice in building before. The pyramid had forerunners, called mastabas (Fig. 6).

No. 1 shows a cross section of the mastaba of King Mena of the First Dynasty. It is just a subterranean burial chamber covered by a solid slab of mud brick. No. 2 is the mastaba of King Djer of the First Dynasty and No. 3 the mastaba of King Den, also of the First Dynasty. You can see how the pyramid shape was gradually approached. No. 4 is the tomb of King Zoser of the Third Dynasty; I called it "tomb" for, as can be seen, it is hard to decide whether this was still a rather complicated mastaba or a pyramid without casing.

The first pyramid which did have a casing, filling in the steps, was that of King Snefru of the Fourth Dynasty, the same dynasty to which King Khufu belonged.

I said earlier that Herodotus was probably told a tall tale when he was informed that the whole nation was drafted by Khufu to build his pyramid. It was an unlikely story in the first place, for one can assume that a pharaoh knew better than to ruin all commerce for years.

But then who did provide the muscle power? No doubt that slaves did work on the pyramid; this is only logical for a slave-holding society. But slaves in general also had other vital things to do.

The most likely answer is that the local *fellahin,* the peasants, were employed once a year.

When the Nile flooded the country, the circumstances were proper for floating in the building blocks. And it was also the time when the *fellahin* had to sit idle,

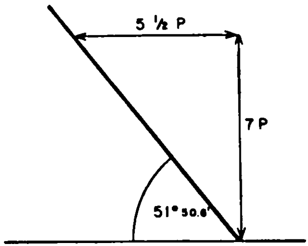


Fig. 5

Egyptian method of measuring angles

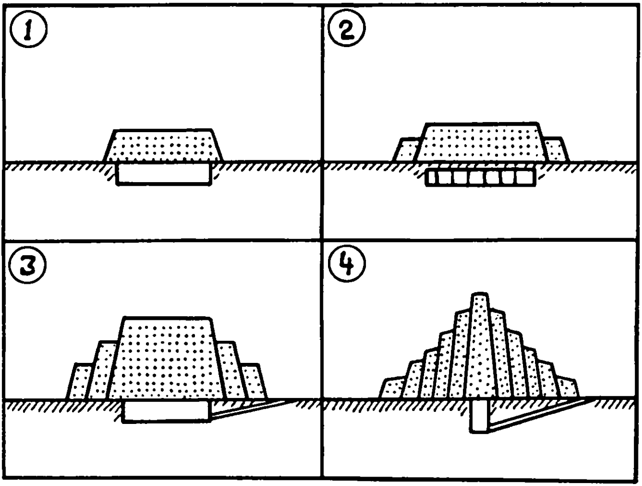


Fig. 6. Forerunner of the pyramids, the mastabas

precisely because their fields were flooded, making it logical to employ them for this period. Maybe the word "employ" is not quite right. They were probably drafted. But we now know that they were paid, mostly in food and clothing.

It is still probable that the overseers carried whips. But they also carried, in the last stages of the building, the triangles made for a slope of 5½ palms per ell of vertical height, the proportion which was destined to cause so much confusion thousands of years later.

— WILLY LEY

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