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SIGVARD HELLESTAM:

THE PYRAMID OF CHEOPS AS CALENDAR

SUMMARY: The two days in the year, when the sunangle at Noon is the
        same as the baseangle of the Pyramid of Cheops, are transition
        days between the three seasons. The baseangle, Seked 5½=11:14, is
        selected so that the length of the seasons, the inundation period
        the growth one and the dry period, are 11-14-11 Decads.

   The Pyramid of Cheops or the Great Pyramid is not only the largest of
all megalitic monuments, but also probably the monument having been
subject to most accurate surveys and most speculation.

One is most impressed during these surveys by the unprecedented exactness
of bearings in the horizontal plane and in the four cardinal points. The
largest height difference around the baseslab with the 230 m side is only
21 mm between the middle of the Northside and the Southeastern corner. The
deviation from the North-South line is only 3´6", i.e. 3/60 of a degree.
1)
The four square corners are laid out with such precision that it is hardly
surpassed by modern building technique. Most exact is the Southwest corner
where the angle is 16", i.e. 16/3600 of a degree too large, and the most
deviating is the Northeast corner with 58" or about 1/60 of one degree. 2)

The North side of the pyramid slants against the horizontal plane at
51°50´40" (51,84°).3) That the precision is extraordinary is evident from
the comparison with the mathematical value of the slant which can be
calculated from the building method. For each cubit of height of the
pyramid they reduced the side of the pyramid by 5 $^1/_2$ Palms. 4) None of
the Egyptian Pyramids either before or after Cheops is as accurately
built. The architect and the builder represented the highest level of a
more than hundred year long tradition of pyramid builders.

The exactness by which the Cheops pyramid was built has caused much specu-
lation not only concerning the religious and cultural motives but also
over the execution and reason for many details used in building. The
reason for the selection of the base angle of the pyramid has not received
as yet a reasonable explanation. It has for sure, from the beginning, been
subject of careful consideration.

What criteria might prevail for the selection of the pyramids base angle?
First, the base angle must be such that the construction will be firm
enough. The enormous weight of a large pyramid exerts great pressure not
only on the bottom but also great pressure on the sides. This requires not
only a very good foundation but also a base angle that is not too great.
In addition to these technical circumstances, one must consider the fact
that the pyramid had to satisfy religious and cultural demands. These
demands could drastically change during the Pyramid Era.

The only practical possibility of building a pyramid side in the desired
baseangle has been mentioned above. The "sidereduction" counted in
handwiths or Palms per cubit was called SEKED by the Egyptians. It was
appropriate to select a baseangle so that a simple SEKED proportion was
arrived at.

EARLIER DEVELOPMENTS

When Imhotep started to add supportwalls to the mastaba of Zoser at
Sakkara during the IIIrd Dynasty he selected the simple SEKED proportion
2. That gave a supportwall with a 74° baseangle. For some reason they
continued to build upwards and to add successive supportwalls with the
same SEKED. The end result was the large Step Pyramid.

The building technique using several supportwalls as coatings outside each
other became the principle of construction when several kings of the IIIrd
Dynasty and later also of IVth Dynasty and Vth Dynasty built their
pyramids. The Pyramid at Meidum, which is considered the first - but not
the first completed - of Seneferus three pyramids, was also started as a
step pyramid.

Seneferu, the father of Cheops, belonged to a new dynasty, the IVth. 5) It
appears that a new religious development took place during the new
dynasty. The King, who earlier called himself Horus, began to be more
linked with the suncult under the Sungod Re, which was confirmed when
Djedefre, the son of Cheops, called himself the Son of Re. Userkaf of the
Vth Dynasty considered himself in the lineage of Cheops, three generations
removed. He called himself a direct descendant of the Sungod Re. 6) The
earlier link to the stellar world did, however, remain. This is evident
from, among other things, the fact that the passage to the subterranean
chamber in the pyramid was still built with a $26-27^O$ slant towards North
in the direction of the Polar Star. 7) This was maintained in all the
pyramids during the IVth Dynasty.

The Mortuary Temple was built on the North side of the Pyramid during the
IIIrd Dynasty but later on the East side, in the direction of the rising
sun. This has been interpreted as the suncult becoming more and more
important.

The transition to the geometrically true Pyramid, i.e. a Pyramid with
smooth facings, also took place during the rule of Seneferu. This has also
been interpreted as a sign of the importance of the suncult. The Step
Pyramid was possibly the symbol for the ladder that the Kings KA could use
to ascend towards Heaven or the Stellar world. The smooth Pyramid facings,
however, could be enterpreted as slanting sunrays blessing the earth. 8)
If the geometrically true pyramid was a sunsymbol, it is plausible that
the baseangle of the pyramid has a connection to a sunangle of special
importance.

Seneferus second pyramid, Dashur South or the Bent Pyramid, was initially
built with a baseangle of $58 - 60^O$. 9) If the principle of the building
technique for the Step Pyramid was used with the supportwalls, which
inclined inwards at an angle of $72 -75^O$, it was logical to attempt to
build a pyramid having a slope as large as 60°. At the suntemple
Heliopolis it had been established positively that, at the Spring and
Autumn equinox, when day and night are equally long, the sun at its
highest point had a 60° angle. The angle is included also in the
aquilateral triangle which together with the circle and square in many
cultures were considered as Heavenly Symbols. In addition, a 60° angle is
easy to use in SEKED 4.

However, at a height of 47 meters cracks started to appear, indicating that the strain on the sides was too great. The base was broadened and sustaining additions were built with a decreased angle of 54°,i.e. SEKED 5. These substantial additions with this lesser baseangle, however, could not prevent additional settlings and the final outcome was the Bent Pyramid with an upper baseangle of 45° or SEKED 7.

Seneferuś third pyramid, Dashur North or the Red Pyramid, was built from the beginning as a True Pyramid with SEKED 7. The building could be completed without troblesome slides or settlings.

The cultural idea that the pyramids had to have smoth sides seems to have gained such strength during Sneferuś later years that it became necessary to add to the Step Pyramid at Meidum for transforming it to a True Pyramid. The eight steps were filled in with horizontal layers so that the baseangle became appr. 52° or Seked 5 $^1/_2$. It is uncertain whether the pyramid was completedly rebuilt or if slides prevented its completion. 10) Today it is known as The Tower of Meidum.

Seneferuś three pyramids consist of 3.600.000 cubicmeter of stoneblocks, which is a third more than what is used in Cheops´Pyramid or the Great Pyramid. His second pyramid and the reconstruction of the first one can be regarded as a testing of the baseangles of the pyramids in the largest building experiment in history. Seneferu finally arrived at a true geometrical shape with the Red Pyramid and its baseangle of appr.45° or SEKED 7. The pyramid was apparently satisfactory from a religious stand-point as Seneferu was probably buried in this pyramid. 11)

CHEOPS - THE SUNGOD

The area that Cheops selected for his pyramid and adjacent city and Royal Palace was the Northeast corner of the limestone plateau next to present Giza. This area was given the name Achet-Chufu, i.e. "Cheops Horizon". The name stressed a connection with, or simply an identity with the Sungod, who each evening disappeared in the western horizon to return again the next morning in the East to give Egypt new life.

The move towards a more dominent sunculture, which began during Seneferuś reign, seems to have culminated with his son, who directly identified himself with the Sungod Re. One of the reasons for locating the new necropolis next to Giza was possibly the vicinity of the temple of the Sungod at Heliopolis. This is situated at Lat. 30°, where the sun on the equinox days is seen in an angle of 60° above horizon or the same angle, which is seen in the Sacred Triangle.

AN ODD ANGLE

Seneferu, the father of Cheops, had after many unsuccessful attempts with various baseangles between 52° and 60° finally selected 45°, Seked 7. That proved to make a stable pyramid. Why did his son not continue with this proven angle instead of selecting 51,84^o OR SEKED 5 $^1/_2$ for his pyramid which, with its predetermind measurements, was intended to be a building of unbeatable size? It must have been a reason of great importance to the country and its King. With the connection between the King and the Sungod

and the importance that the Sun and also the Nile had for the wellbeing
of Egypt, it was probable that the angle could relate both to the Sun
and the Nile.

In order to be really successful with his building of the Pyramid, the
design was carefully made, both as to location and as to details in con-
struction. The safety was carried so far that the Pyramid became overly
strong.

THE EGYPTIAN CHRONOLOGY

It was of utmost importance to life and culture in Egypt that the
farmers could produce a surplus of farm products. A prerequisite for this
was that it would be possible to determine the beginning and the end of
the three seasons that were in use, i.e. the yearly flooding of the
Nile, the growth period and the harvest period in the dry season. 12).
The water of the Nile started to rise roughly simultaneously with the
sighting of Sirius or Sothis, the powerful star, over the eastern horizon
just before sunrise. This occurred in the Memphis area at the height of
summer or the Solstice.

 The oldest calendar was the mooncalendar with a synodic month averages
29,53 days. This made it possible to divide the year into 12 months with
30 days each. The five extra days in the year were celebrated as
holidays. This 365-day year seems to have been introduced as a civil
calendar around 2800 BC and was adopted for administration purposes.
Since the earth needs 365.24 days for a revolution around the sun, this
means that Sirius rose over the eastern horizon a quarter of a day too
late for each year. If one started to calculate New Year from Sirius
ascent, in following years the New Year would occur earlier each Summer
and Spring. After 120 years the New Year would start one month earlier.
After approximately 1460 years, the New Year would again coin-
cide with the appearance of Sirius. This period is known as the Period of
Sothis. It is known that the year 139 A.D. was a Sothis year. By counting
backwards it is possible to determine that the years 1317 and 2773 B.C.
were Sothis years. 13)

But Egypt also possessed at this time a "Nile" lunar calendar based on
Sothis. 14) The commencement of this year was kept by intercalation of a
thirteenth month when necessary at the last new moon before heliacal
rising of Sothis or at the first new moon after the solstice.

Over the centuries the idea would grow that months grouped themselves
into seasons, each one lasted about four months. Each month was divided
into three parts of ten days each (decade). The thirty-six decades of the
year were connected with the thirty-six stars or constellations, which
rose during the twelve hours of the night.

As the sunyear is 5-6 days longer than 36 decades, it may be an error of
1-2 days in the length of every season.

Even if the flooding of the Nile took place at regular intervals, it was
possible at times to note rather considerable differances between the
occurrences. It is known that between 1945 B.C. and 1875 B.C. the time
between the floodings varied between 345 and 415 days, thus a difference
of over two months.15)

These irregularities - that the New Year wandered in the Sunyear and that
the floodings could occur with very variable timedifferences - must have
caused a considerable problem for the Egyptian administration when the
calendars were being systematized. Aside from the observation of Sirius´
rise one could have been very anxious to arrive later in the year at
fixed times for the growth season and the beginning of the dry season -
thus the transition between the three seasons. It seems natural that the
administration of Cheops, with their new relation to the Sungod would try
to find these fixed timepoints related to the sunyear.

THE SUN ANGLE AT 12 NOON

It is assumed that the priests in the suntemple at Heliopolis were able
to track the passage of the sun very carefully. A simple method was to
follow the shadow of a vertical column. The direction of the shadow
showed the time of the day, while the length of the shadow could be used
as a calendar for the sun year.

 If the length of the shadow of the sun was measured during a year and
proportioned to a column with a height of 1 Cubit they could have found
the following figures for some of the decades

	Decade	Seked	Sunangle	o
Solstice	1	ca 3 Fingers		84
Aut.eqinox	9	ca 4 Palms		60
1st to 2nd seas.	11	5 1/2		52
Winter	18	9 1/2		36
2nd to 3d seas.	25	5 1/2		52
Spring equinox	27	4 Palms		60

The length of the three seasons are supposed to be 11, 14 and 11 decades
respectively. It is noticeable that the sunangle- proportion at the
transition-days, 5 1/2 to 7 or 11 to 14 is the same as the proportion
between the length of the seasons, 11 to 14 to 11.

The baseangle of the Pyramid of Cheops could thus have been selected to
get a simple method to find the day for transition between seasons. When
the sun at Noon was shining alongside the North side of the Pyramid, it
was the day of changing fom the inundation season to the growing season
or from that season to the dry period. 16)

By using this baseangle in his Pyramid Cheops wanted to connect for
eternity the two most important elements for Egypt, i.e. the Nile and the
Sun with periods which were independent of wandering New Year and thus
give the Egyptians a reliable calendar.

The same ambition could possibly be found in Seneferu´s time. The last
building attempt at Meidum seems to indicate this. But it was Cheops who
succeeded with the help of an extraordinary architect.

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ANNOTATIONS

1) Stadelmann p.108
2) Stadelmann p.220
3) Stadelmann p.108, possibly the North side
4) The Egyptian measure One Royal Cubit was divided into 7 Palms, each
   equal to 4 fingers, 1Cubit=52,4 cm
5) Seneferu is considered to have ruled for 40 years, from c:a 2640B.C.
6) Stadelmann p.164
7) The Polar Star was Alfa in the constellation Dragon $3^o43'$ from Celes-
   tial Pole. A passage to a grave pointing toward North with $26^o17'$ was
   pointing exactly at the Polar Star.
8) A cone would have been a better symbol but very difficult to build.
   The symbol of the sungod at Heliopolis was a golden cone "BENBEN",
   according to Mendelssohn p.73 and p.185.
9) Stadelmann p.89-90
10) Stadelmann p.86. Perhaps the Meidum collapsed during the time of
    Seneferu, Mendelssohn p.156.
11) Stadelmann p.86
12) Gillings p.235
13) Parker p.52
14) Gardiner p.205
15) McLeish p.58. Parker p.32 states that during the 32-years period
    1873-1904 AD the shortest period between two floodings was 336 days
    and the greatest was 415 days.
16) The sunangle as a function of time f.ex. the decades is practically
    a Sinus-function. That the earth rotates around the sun in an
    ellipse instead of a cirkle makes a little difference especially
    wintertime. In Fig.1 the sunangles calculated from figures in The
    Nautical Almanac are plotted together with a sinus-curve.
17) A pyramid with a baseangle of $51,84^o$ has several interesting charac-
    teristics. The Egyptian designated the angle as SEKED 5 $^1/_2$. This is
    the same as 5 $^1/_2$: 7 or 11 : 14. The Egyptian architects frequently
    used when building temples or pyramids a relation 3:4 or 7:9, see

Bent H Hansen, Akten des vierten int. ägypt. Kongr. München, 1985.
Riedel, p.108, mentions that several well-known archaeologists had
considered a relation of 11:14 to be the reason for the baseangle.
It is possible that a circular disc was used when measuring the
shadow of the sun. If its diameter was 1 cubit and the height of the
column was 4 cubit the length of the shadow corresponded exactly to
one turn of the disc at a sunangle of 5 $^1/_2$ SEKED. This was due to
the relation 11:14 also being equal to Pi:4. According to Mendels-
sohn the disc was used to mark off the measures of the Pyramids
baseplate. Thus Pi became "built-in" to the base/height relation of
the pyramid.The Egyptians did not know of Pi until much later.
An additional interesting measurement relation is that half the
baselength corresponds to the height of the side of the pyramid as
o,613 i.e. THE GOLDEN SECTION, down to three decimals, Check Stadel-
mann p.268.

P.S.

In calculating the angle of the sun it must be considered that the
pitch of the Earths exis against the ecliptic has changed during 4600
years as compared to the present. The change is calculated with
Newcombs formula for the ecliptic oblique to be +35,i.e. that the
earths axis at the time of the building of the pyramids had to have a
pitch of $24^{0}02$. The so called precession, which means that the earths
axis turns around a double cone in 26000 years brings about a shift
in the seasons and location of the stars. This, however, does not
make any appreciable change in the pitch towards the ecliptic.

FIG. 1   SUNANGLE AT NOON