PRECESSION: AND THE PYRAMIDS

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TO be told that five thousand years ago the Southern Cross could have been seen by one standing where London stands to-day would certainly cause most people surprise. Nevertheless such was the fact. That celestial asterism to which persons who have not seen it look forward as to one of the revelations incident to voyages into the tropics and then, on beholding it, feel egregiously duped, needed then no far travel to disclose. The sad disillusioning caused by its rising could have been enjoyed without leaving home. For 3000 B.C. its center-void apology for the real thing might have been observed above the outline of the South Downs at midnight at the proper season of the year by a stargazer at the then mute and inglorious Greenwich.

If amazed at the apparition our tourist thus transported back in time turned to get his bearings from the north, not less astonished would he be to discover his old friend the pole-star unaccountably gone. Even the learned might experience a shock. Certainly to those who drink in their star-knowledge through the medium of the Dipper would it prove disconcerting to find Polaris adrift in the sky. Its fixity fled, our cynosure would indeed be difficult to detect. Just as mediocrity exalted by office sinks into plucked insignificance once its insignia are removed. Nor would he find the solace of familiarity anywhere else. For such upsettings of fundamental fact would confront him everywhere. The whole firmament would appear to be turned topsy turvy could we suddenly be canopied by the heavens of those departed days. All the constellations would seem askew even if he succeeded in making them out. Nothing new under the sun! perhaps; but a very different state of things under the midnight stars.

Such a thorough change in outlook upon the universe is certainly no mean event and serves to point the importance of a subject in astronomy well worthy of engaging general attention, the more so that it is intimately associated with man. For this revolution in the sky is brought about by what is called the precession of the equinoxes. The name is due to what first disclosed the action. Primitive man framed his calendar by the stars. Not having the benefit of an Old Farmer's Almanac with its superannuated tillage advice, the husbandman then judged his seedtime and harvest by the constellations that rose in the morning just before the sun. How long he placed implicit confidence in such chronology after it became out of date we can but surmise. For that the stars and the seasons which they ruled did not continue to agree must have been early evident to the astronomer-priests who made a study of the two the basis of their calendar and of all the functions, aratral and religious, appertaining to it. So that the stellar springtime of one year was not the springtime of the next. That the zodiacal constellations were continually moving forward to meet the sun in his yearly round of the sky could hardly, one would have supposed, have escaped the observation of antiquity. Yet we find no mention of the fact; not so much as an ascription of the incongruity to the errors of predecessors.

To Hipparchus is due the honor of its discovery; a detection brought about in this wise. Besides watching the heliacal risings of the stars the ancients had another way of determining the date of the vernal equinox: this was by noting by the gnomon of a sun-dial the times when the shadows cast by the sun at noon were longest or shortest. This gave them the dates of the solstices. Hipparchus by comparing his own observations with those that had preceded him—on Spica, chiefly— found that the two methods did not agree but that the equinox as set by the sun stepped forward to meet the stars by about twenty minutes each year. As he perceived that while the longitudes of all the stars were thus changing, their latitudes remained the same, he concluded with the astuteness of genius that it was the equator that was moving, not the ecliptic; that is, the earth's tilt was shifting not the sun's.

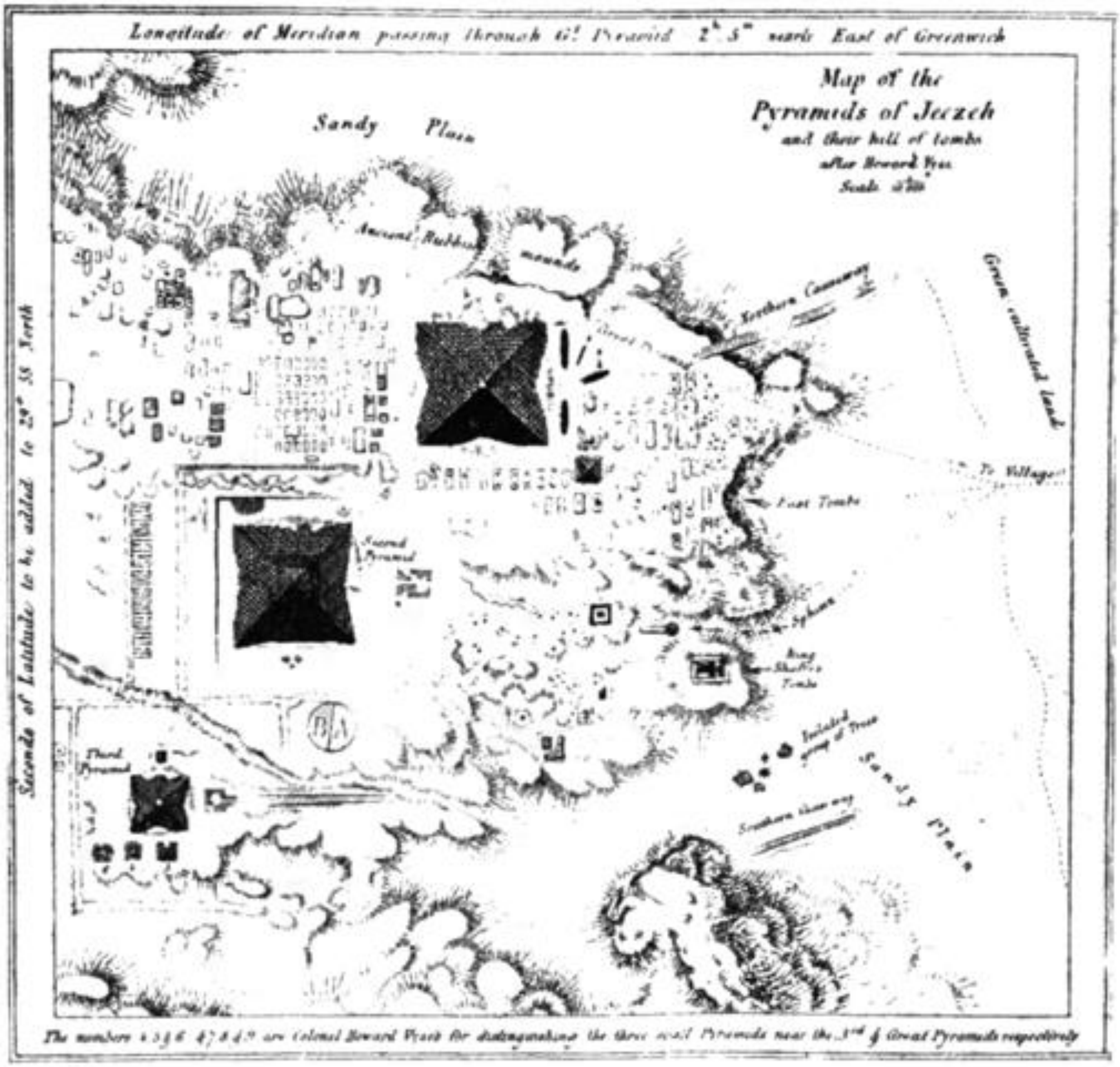
The merit of Hipparchus in the matter was two-fold: the ability to discover the thing and then the courage to proclaim it. For in the good old times men were no quicker to recognize advance than they are to-day and were just as possessed to denounce it. In consequence Hipparchus's discovery suffered the usual fate of new truths. Some astronomers disputed his facts, others explained them away as an oscillation merely, while yet others simply ignored them. In spite of which mundane anathema the slow movement of the equinoxes went obstinately on.

This mighty revolution of the equinoxial points by which spring opens twenty minutes earlier each year Hipparchus was not able to explain. He noted the fact, which was a feat remarkable enough, considering his means. Indeed, he probably never tried to penetrate further into the mystery. The Greeks were better geometers and more discerning reasoners than we were brought up at school to believe, but in astronomical matters a great gulf lies between them and modern thought. They never conceived the principle of universal gravitation. Failing this, it is no wonder they never imagined to what precession could be due. For the realization of this result of gravity is a much more advanced step in celestial mechanics than the accounting for the circuit by the planets of the sun.

Not wholly easy at first of comprehension, appreciation of the principle which underlies it will be found well to repay the trouble it costs. For to master it is to put one's self in possession of a celestial time-piece one hour of which is 25,700 years and whose minute hand traces out the lapse of centuries upon the dial of the sky. Not only as a clock is it a possibility, but as we shall see it has been actually so used unconsciously by man in days gone by, and his readings of it recorded in lithographs still legible to-day.

To understand its working we must in thought get off the earth and see that body from without. We should then perceive our globe as a mammoth top spinning in the sky as it moves along in its orbit. The spin gives us our days, and as the equator is tilted to the path the pull of the sun is all the time trying to bring the one to coincidence with the other. If the earth were perfectly round there would be nothing for the sun to grasp and the spin would remain unchanged both in amount and in direction. The earth, however, is not round, but spheroidal, bulging at the equator. There is thus a handle, two handles in fact, which may be used for turning it. Now suppose the earth in the position of its summer solstice when its axis is tilted away from the sun in a plane containing the sun and a perpendicular to its orbit. The attraction of the sun tends to rotate it in this plane. Meanwhile the earth is spinning round its own polar axis at right angles to that direction. We have then to compound two spins about axes perpendicular to one another. Curious as it may seem, the result is not to pull the bulge down into the orbit plane, but to make it back bodily along the ecliptic. It is as if the earth resented the sun's attempt to right it and with almost human perversity went the other way. Indeed one may feel the obstinacy of the thing by appropriately pressing on a gyroscope, when instead of yielding it will promptly buck against you with a force suggestive of intent. The greater your shove the faster its opposing speed. Now with the earth the pull of the sun is feeble compared with the great moment of momentum of the earth, and in consequence the motion of the earth's pole is most leisurely. The backing of the equinoxes to meet the sun is but 50″.23 a year and the time it takes to complete the circuit of the zodiac 25,700 years.

The figure of the earth exposing it to such action, any body may set it spinning and all do. The amount and direction of the spin depend on the position, of the disturber. Because the greatest, by precession is usually meant the luni-solar precession, caused by the combined action of the sun and moon. In this the moon is about two and one eighth times as effective as the sun in spite of its relative insignificance because of being so much nearer. The amount of the precession depends among other factors upon the cosine of the obliquity of the ecliptic. The greater the obliquity, therefore, the less the precession. At the present moment the obliquity is diminishing and the precession increasing. This will continue to be the case for several thousand years.



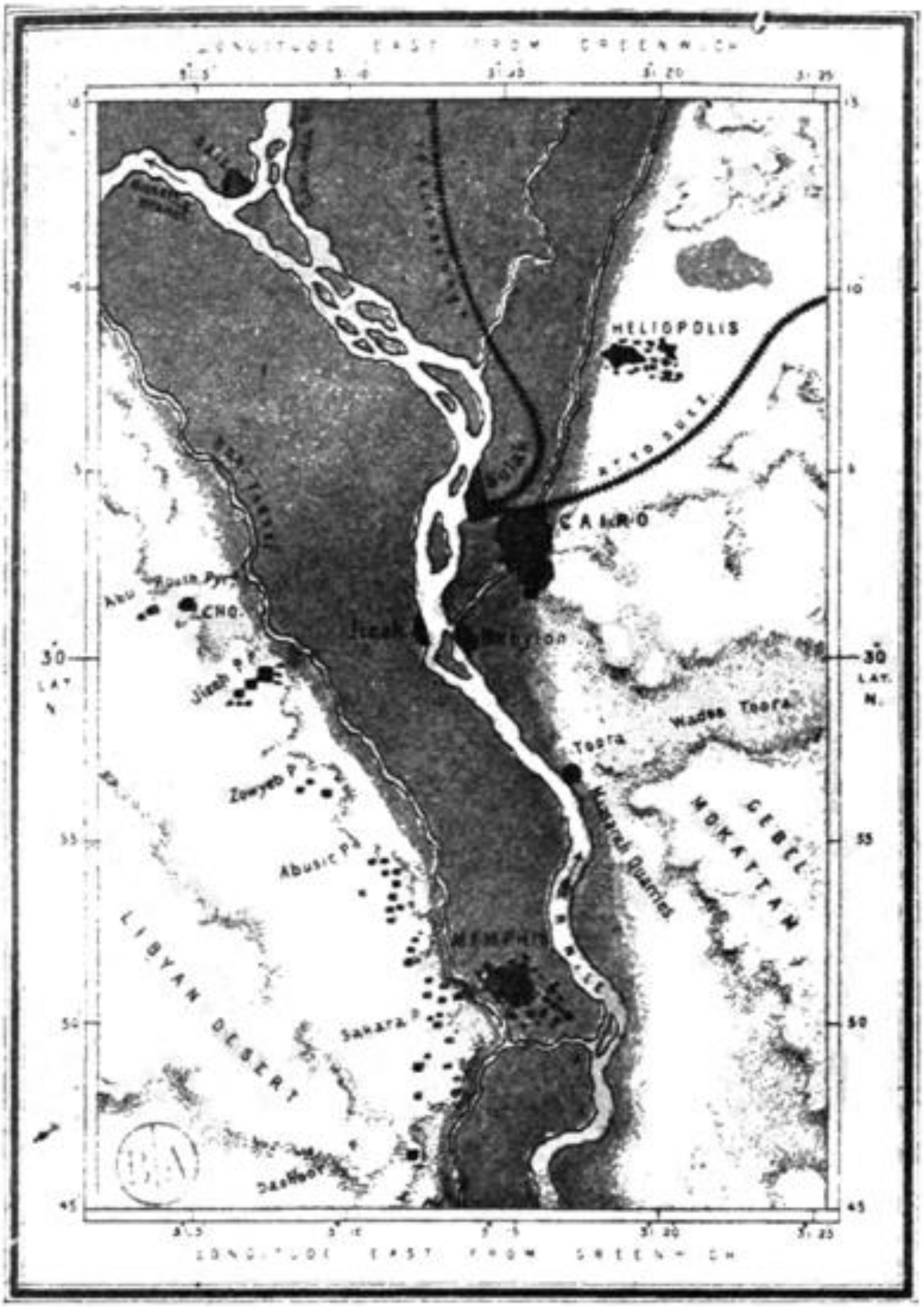
MAP OF THE PYRAMIDS OF JEEZEH.

Besides this precession another or, more properly speaking, several others are produced indirectly by the action of the several planets upon the plane of the ecliptic. As these bodies are out of the plane themselves their action pulls the earth out of her orbital plane, causing a change in the obliquity of the ecliptic. There is in consequence a slow alteration in the place of the pole of the ecliptic and this results in a movement of the equator other than what the sun and moon produce. It is known as the planetary precession. Chiefly by such round-about process do the planets make themselves precessionally felt. For all of them, even Jupiter, are relatively too small and too distant to have their direct pull upon the earth's equatorial ring of any account. The direct precession due to Jupiter is only about 0".0001 a year and that caused by any other planet much less.

As all the planets are concerned in the work, and as they are all pulling different ways, the combined effect is not regular in either extent or duration, although there is a general swing to and fro of the ecliptic as the result. Its periods are much longer than the luni-solar precession. Thus, according to Leverrier, the one now going on had its maximum effect about 40,000 years ago and the next will be 35,000 years hence. This may be taken as about the mean swing; which shows that it is thrice that of the precession of the equinoxes properly so called. It is so combined with the latter, however, that though quite extensive in itself, amounting to more than 4°, it can never change the tilt of the ecliptic to the equator by more than 1°, one third on either side, so that our seasons can never differ greatly from what we know them now. They can neither be materially accentuated nor proportionately reduced.

Though the obliquity of the ecliptic is oscillatory, the motion of the ecliptic pole keeps persistently, though unsteadily, on always in the same sense. Its wanderings trace out an elliptic spiral which never returns into itself. Its vagaries resemble as much as anything an unevenly bent spring carelessly coiled about a mid-position from which it never far departs.

Meanwhile our own pole pursues its relatively sedate march around the other, permitting its position to be calculated at any past epoch not too remote. We can plot its path and thus see near which stars it passed, stars which had the earthly distinction once upon a time of being our cynosure. In this manner we discover that 4,690 years ago, or in 2780 B. C., the pole passed within 3' of arc of the star *α* Draconis. Practically the star was the pole, and it was the last bright star the pole approached before reaching Polaris. In the time of Hipparchus, 140 B.C., the pole lay undistinguished in a waste region of the sky. *A* of the dragon is now a star between the second and third magnitudes, but there is evidence to show that in ancient times it was brighter. It must



MAP OF THE NORTHERN PART OF THE ANCIENT PYRAMID FIELD IN EGYPT.

therefore have been a fine pole-star in its day, both because of its nearness to the pole and because of its own intrinsic brilliancy.

Of interest as this is from an academic standpoint, it becomes impressive when we learn that this prophecy about the past was contemporaneously verified and witnessed, as unconsciously as it was conclusively.

Not only was α Draconis once the pole-star, but it was actually so seen of men who have left us record of the fact. And this, too, without the slightest idea that they were dating history, and in the most dramatic manner possible. Not by carved or written inscription, not by oral tradition handed down by word of mouth, was this accomplished, but in a way at once more silent yet more sure—mutely embodied in the very core and being of a building the grandest ever erected by man. The Great Pyramid, the pyramid of Cheops, tells us this in stones that bear no character at all and only astronomy can read.

Herodotus, the "Father of History"—known also as the father of lies in what may be called the Ananias Club sense, for we are now learning that what he narrated, though seemingly unbelievable, usually turns out to be true—informs us that when he was in Egypt he was told by the priests that a long time before certain peoples had come down from the north, possessed themselves of the Egyptian power and so far affected the mind of the then King Cheops or Suphis that he forsook the Egyptian religion, caused all the temples to be closed and set to work under the stranger's direction to build a huge pyramid of stone.

The same veracious if also voracious historian goes on to say "that 100,000 men were employed for twenty years in building it; that Cheops was succeeded by his brother, Chephren who followed his pyramidal example; and that by the space of one hundred and six years all the temples of the kingdom were closed." In consequence the pious Egyptians deprived of their natural religious vents "detested the memory of these kings"; as they may well have done for other than religious motives, seeing that they were employed at forced labor on such a scale for such a length of time.

Manetho, who confirms the royal apostasy mentioned by Herodotus, gives us to suppose that we have here an invasion of the shepherd kings about the time of Abraham. Their force seems to have been intellectual, as they overturned the whole Egyptian system of things, he says, without a battle. So that they were probably Chaldeans, and the pyramids which they caused the king and his successors to construct were not Egyptian monuments at all, but embodiments of a foreign cult peculiarly distasteful to the followers of Isis and Osiris. Indeed, as we shall presently see, they were neither Egyptian nor monuments.

What they were not is plain; what they were has best been deciphered by Proctor, who has shown well nigh conclusively that their purpose was astrologic. That they were astronomic constructions they themselves reveal, and the only rational explanation of the power the strangers gained over the mind of the king lies in the astrologic art the Chaldeans are known to have possessed, and which is also known to have been eagerly sought after by all the peoples of the east.

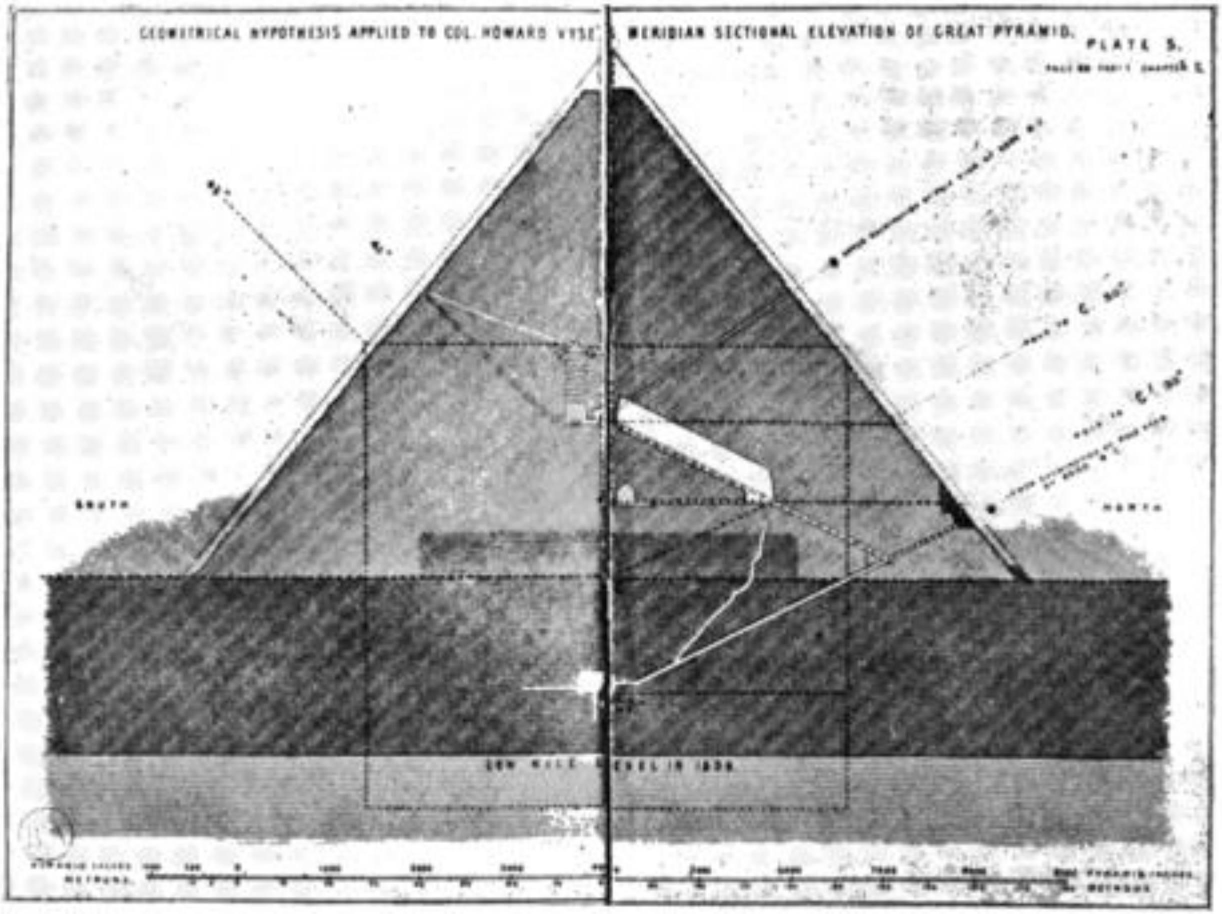
Both without and within they testify to a very heavenly regard on the part of their builders. In the first place their situation is expressive. They stand within a mile of the thirtieth parallel of latitude and undoubtedly were only prevented from standing nearer that astronomic line by the fact that the plateau shelf on which they were erected here falls abruptly to the plain. At this point on the earth the north pole is 30° high, and thirty degrees has this commendation to geometers, which the pyramid builders emphatically were, that a perpendicular from it to the line of sight is at that elevation exactly half as long as the line of sight itself.

In the next place the base of the building is four-square, its sides being oriented to the compass points with surprising accuracy. Just as Christian churches face the east, that is Jerusalem, and Mohammedan ones Mecca, so the pyramids faced the north. Here then we have surmise of both religion and astronomy, to wit astrology, embodied in the mere outward aspect of these constructions.

This is, however, as nothing to what the interior reveals. Upon the north face of the Great Pyramid a passage opens, descending for 350 feet through tiers of stone at first, then through the solid rock. This passage points to the north within 4′ or 5′ in azimuth, is perfectly straight and is inclined to the horizontal at an angle of 26° 26′. The long straight hole suggests that it was used for looking at a star, for down it a bright star might even be seen by day. Its direction, moreover, hints that the pole-star was the one in question. Now the latitude of the pyramid is 29° 58′ 51″. The subterranean tube, therefore, does not look directly at the pole; but when we take refraction into account we find that it would look exactly at a star distant 3° 34′ from the pole when that star was at its lower culmination, that is, passing the meridian directly south of the pole.

Now if in latitude 30°, a man wished to observe the north or south passage of a circumpolar star, in order, for example, to ascertain true north, the best means of doing so would be to dig a subterranean passage-way pointing approximately northward and then mark through it when the star ceased to rise or sink; and since either culmination would suit him he would naturally choose that one in which the slant of his tunnel would be the least, both because he could dig it easier and because he could descend it best. An incline of twenty-six degrees is distinctly preferable to one of thirty-four. Now 645 years before or after the date when Draconis was approximately upon the pole, it was 3° 34' distant from it; that is, in B.C. 3430 or B.C. 2140. The passage, then, chronicles the time when the pyramid was built—with a seeming choice of alternatives. But the nearer of these is negatived by what we know of Egyptian history and we are thus left with the other, that of B.C. 3430, as the date of the pyramid's construction. The pyramid thus dates itself astronomically, which is the first remarkable thing about it.

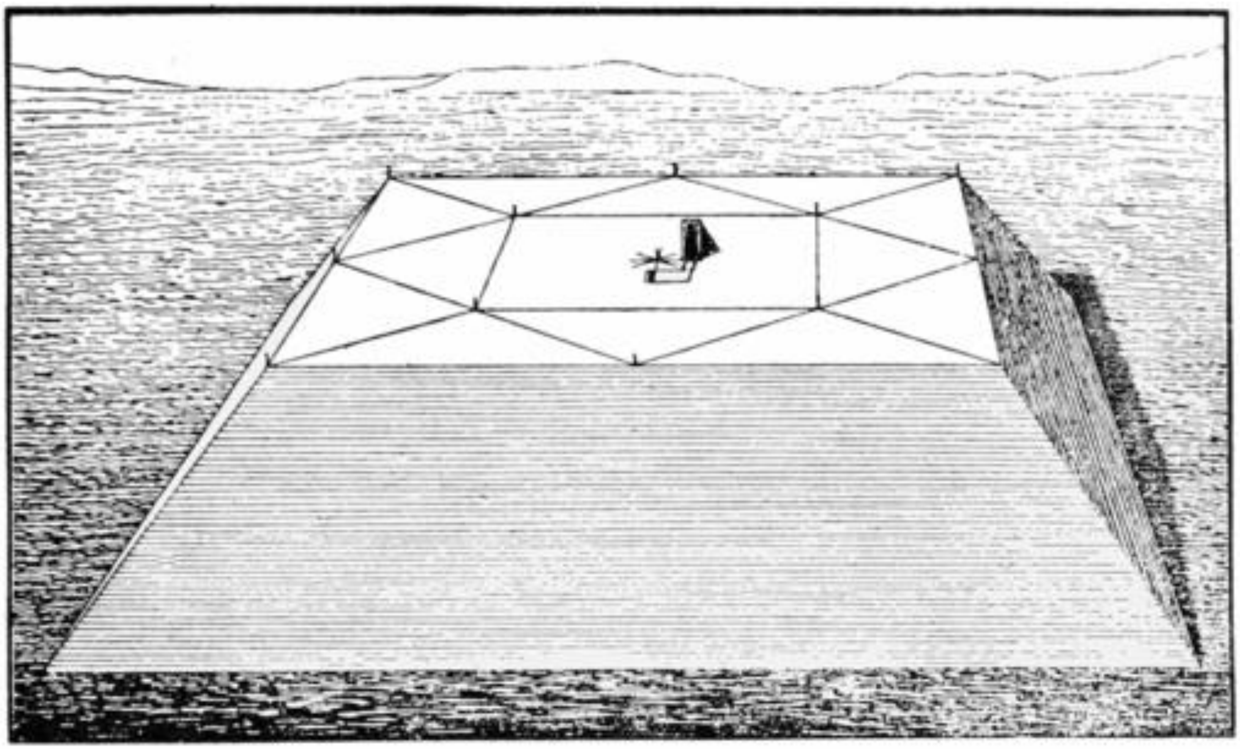
It is to be noticed that astronomy here furnishes Egyptology with a fixed epoch from which to go forward or back. We are not here dealing with conjectures as to when a certain king or dynasty can be made



Geometrical Hypothesis applied to Colonel Howard Vyse's Meridian Sectional Elevation of the Great Pyramid.

to fit into a general chronologic scheme by the relics it has left us of itself. Calculations from known astronomic data can tell to an exactness gauged only by the size of the opening of the passage as seen from below precisely when the pyramid was built with only the choice above described. To deny which would but argue a lack of appreciation of physical science. For that such a pointing can be but the sport of chance, the whole structure of the pyramid emphatically denies.

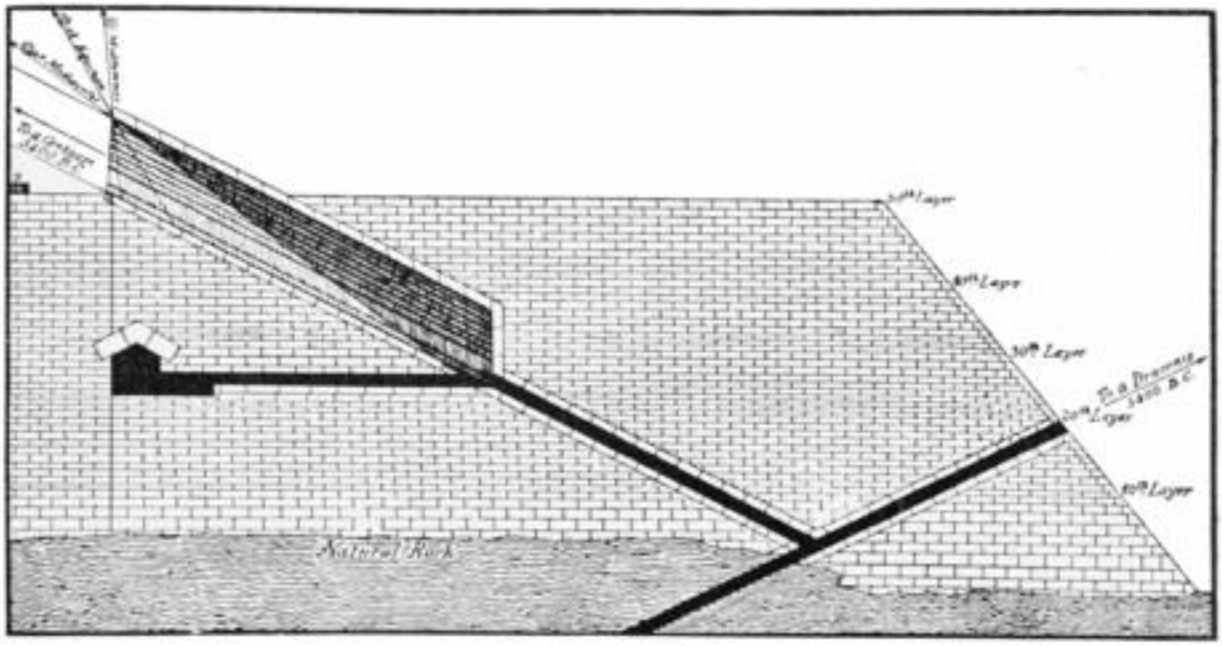
The Great Pyramid was in fact a great observatory; the most superb one ever erected. The building is the most mammoth in the world, and it had for telescopes something whose size has not yet been exceeded. This something which did those old astronomers for instrument was the Grand Gallery. As its name implies this was a stone gallery of imposing proportions set on an incline of 26° 17' in the very heart of the structure and pointing south. It is approached by the



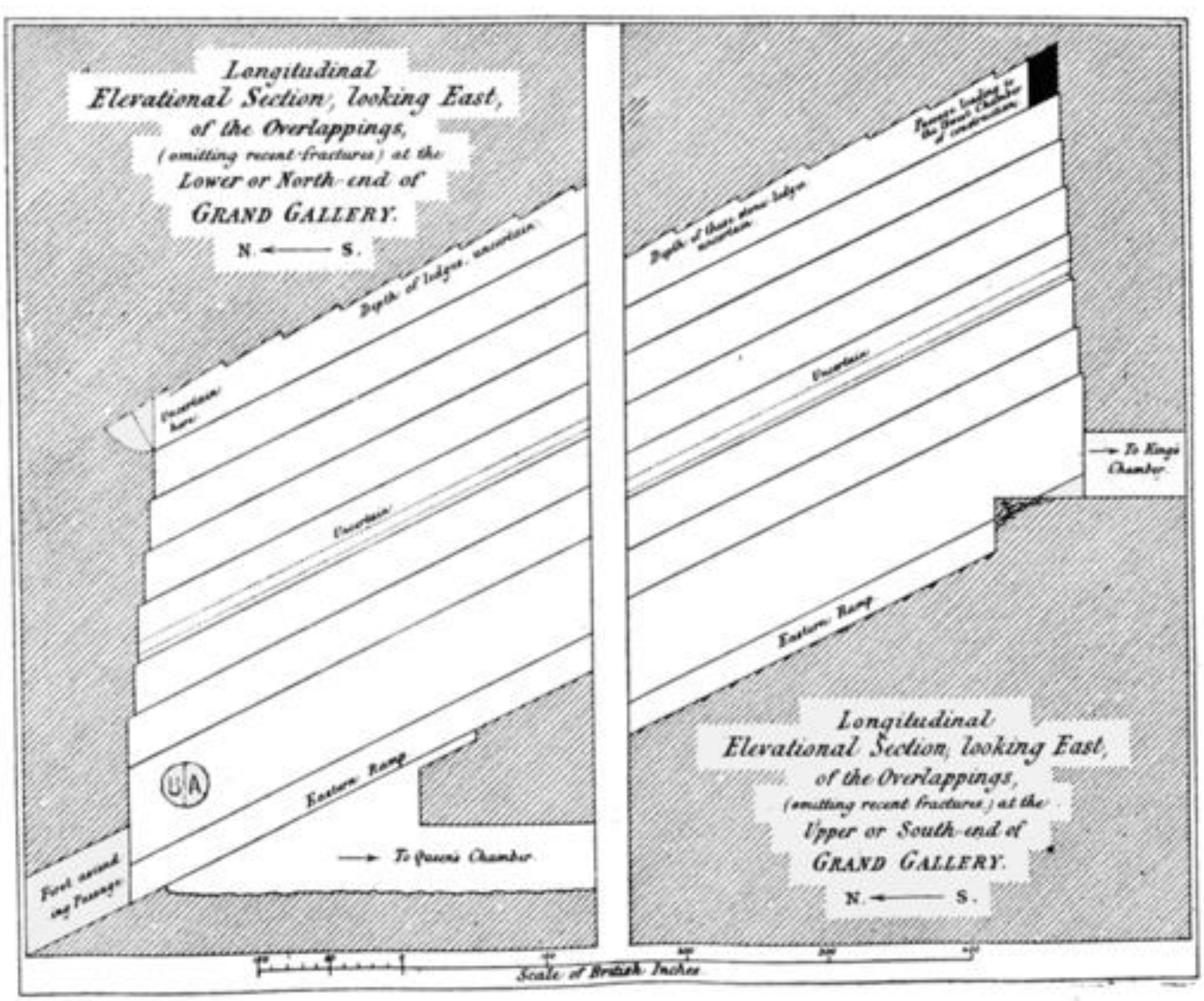
THE GREAT PYRAMID OBSERVATORY.

descending passage which looked at the pole-star and thence by an ascending one at about the same angle which opens into it. It is one hundred and fifty-seven feet long, twenty-eight feet high and about eight feet wide. Along the center of its floor a smooth stone flagging ascends, flanked on either side by raised curbs or ramps half as wide each as the central paved pit. These curbs are not continuous but are cut at approximately equal intervals of about five and a half feet by notches with vertical edges. There is no doubt that these were for the insertion of benches, as the notches tally on opposite sides. At about sixteen feet from the bottom the central incline stops in a vertical wall which descends to a horizontal pavement, giving entrance to the corridor which runs to the Queen's apartment.

The roof of the gallery is everywhere smaller than the floor, so that



VERTICAL SECTION OF THE GREAT PYRAMID, SHOWING THE ASCENDING AND DESCENDING PASSAGES, GRAND GALLERY AND QUEEN'S CHAMBER.



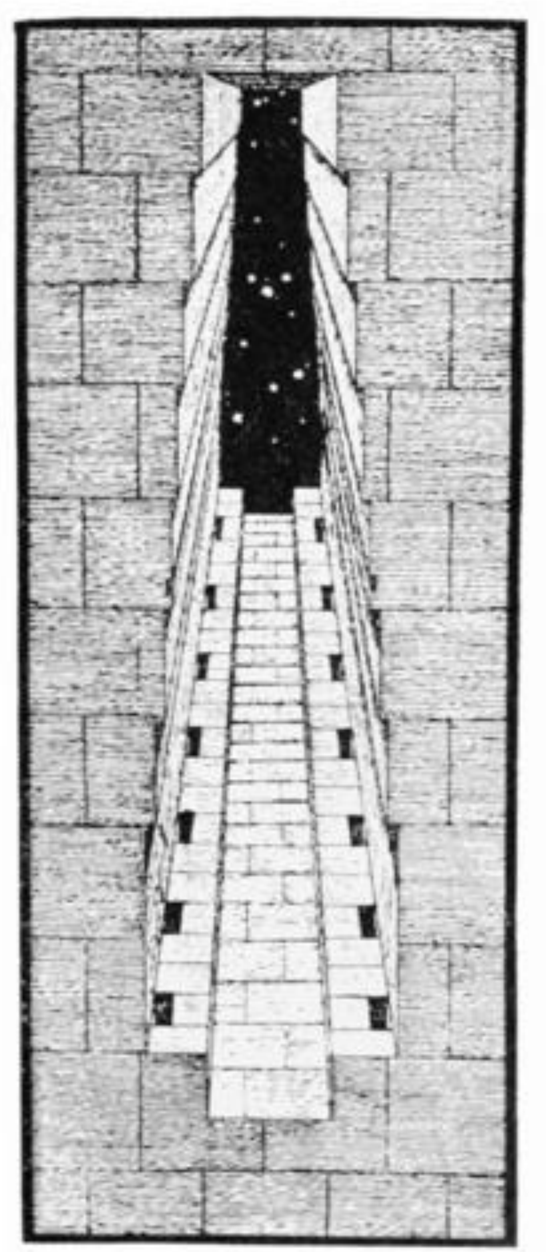
LONGITUDINAL SECTIONS OF THE GRAND GALLERY.

it overhangs the bottom about one foot eight inches on three sides, 39.5 inches at its southern top. The stones on the sides are carefully set in tiers, the sides themselves being oriented to the compass points. Its exact dimensions which we shall find telltale are:

	Inches
Inclined length of floor	1,815.6
Same produced to south walk	1,883.0
Height	339.0

It is now of course walled in by stone on every side, but in the day of its use it undoubtedly stood open at the top, the horizontal passage in which it now ends at the summit having been the beginning of the platform of the whole pyramid, at that height. No records tell us this; our information comes from the gallery itself. Now if we calculate the angle from the vertical which the end of the cornice makes with the upper end of the floor we shall find it 6° (6° 20'). Remember that the gallery faces due south, so far as the builders could place it, that the latitude was 30° (29° 58' 51") and that the obliquity of the ecliptic was then 24° (24° 4'). Now subtract the second angle from the first to get the altitude of the sun at the summer solstice, and we have 6°. Consequently at that season the shadow of the gallery roof would just strike the south end of the gallery floor. A curious astronomic coincidence, you say. But go a little further. Let us calculate the angle from this same coping down to the end of the central incline on the gallery floor. It comes out 36° 10'. Now at the winter solstice the sun was 30° + 24° from the zenith or 54°, that is, 36° from the horizon, the angle just found. In midwinter then the sun shone just to the bottom of the effective gallery, as at mid-summer it had marked its top. Between these two extremes the shadow must always fall. Thus the gallery's floor exactly included every possible position of the sun's shadow at noon from the year's beginning to its end. We thus reach this remarkable result that the gallery was a gigantic gnomon or sundial telling, not like ordinary sun-dials the hour of the day, but on a more impressive scale, the seasons of the year.

That the gallery itself extends below the point where the central incline drops vertically to permit of entrance to the Queen's Tomb with its ramps notched, as above, does not vitiate the deduction, for observers could not generally be placed on benches with their legs hanging down, however they might be so located on emergency. The recognition of this function of the gallery is not new, being, I believe, due to Proctor, but the exact coincidence of the limits of the effective gallery with those of the sun has, to my knowledge, never been pointed out.



THE GRAND GALLERY.
VERTICAL SECTION THROUGH

Such, then, was the use of the entering passage, and such the design of the Great Gallery. Grand as was communion there with the sky by day, it must have been sublime at night—alone with the stars in the heart of that superb monument of stone. About the year B.C. 3430 it was further heightened by a spectacle which could not be witnessed now. Calculation shows that the great star *α* Centauri, the brightest and nearest to us of all the fixed stars, shone then at its upper culmination night after night down the hushed and polished vault of the Great Gallery.

α Centauri now hardly peeps above the pyramid's horizon at its highest, and in a few more years will never rise there at all until, thousands of years hence, the pole in its majestic precessional march raises it into view once more.

In a peculiar sense the pyramid was the man for whose use it was built. Primarily its purpose was to cast his horoscope through life, and then when his days were ended it became his tomb. He was buried in its interior. What had been its astrologic platform on top was continued on to an apex and then the whole structure sealed up, to remain, so it was fondly hoped, inviolate through time.

One reflection well worth our thought the pyramids suggest: the enduring character of the past beside the ephemeralness of our day. We build for the moment; they built monumentally. True we have printing which they had not. But libraries are not lasting. Fire accidental or purposive has destroyed the greater part of the learning of the far past and promises to do so with what we write now; and what escapes the fire mold may claim. Only that idea which is materially most effectively clothed can withstand for long the gnawing disintegration of time. The astronomic thought of the pyramid-builders lives on to-day; where will record of ours be, I wonder, five thousand years hence. We may be quoted indeed with ever-increasing inaccuracy of transcription, but the star-priests of α Draconis's time speak in their own words still.

To us Cheops is hardly more than a name; long since his ashes were scattered to the winds; but the building those old Chaldean soothsayers constructed for him remains, not only to-day the grandest monument of man but the oldest and most significant astronomical observatory the world has ever had.