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The Sacred Craft: African Systems of Architecture

"Modern" architecture . . . started on a sound basis but has . . . , more often than not, ignored this human scale. Some architects have gone so far as to . . . ignore symmetry in religious architecture, which has consequently become grotesque.

—Alexander Badawy, *Architecture in Ancient Egypt and the Near East*, p. v

It has been much commented upon but poorly appreciated how much African architecture derives from its environment. In the Nile Valley, for example, the traveller may visit the monumental sites repeatedly for years before it dawns on him that those peerless builders drew their inspiration from nature. The mastabas, stepped pyramids, bent pyramids, "true" pyramids, not to mention the mounds and tumuli resting in silent profusion in the regions of the upper cataracts, did not emerge unbidden out of the imaginations of the early architects. This truth is brought home with startling clarity when flying over the desert just west of the Nile at Abu Simbel, where all the classic Nile Valley architectural styles repose stolidly in the landforms and rockscapes dotting that locality, etched into these geometrical shapes by the master hand of nature.

The civilizations and cultures of antiquity never lost their awe of nature, and the idea of "imposing" the will of man upon her was beyond conception. Thus, the edifices erected by the superlative Nile Valley architects of antiquity seem not merely to blend with the landscape but to emerge from it. The builders took extraordinary pains not to distort the landscape in any way; the material form of civilization was subsumed by nature. Hatshepsut's Deir el Bahari was carved out of and merges with the base of the massive cliffs rising straight up on the Nile's west side opposite Karnak Temple (see Plate 15). Moreover, it was possible as recently as a century ago to wander all over the Valley of the Kings without ever suspecting that one was surrounded by 62 extensive tombs. The tombs of the Nubian nobles at Aswan are, likewise, not immediately apparent to the eye unless one knows what one is looking at.

Similarly, the massive stone walls forming the perimeter around the hill enclosures at the Great Zimbabwe site incorporate the huge boulders and granite outcroppings that dot the region. Indeed, some enclosures conform

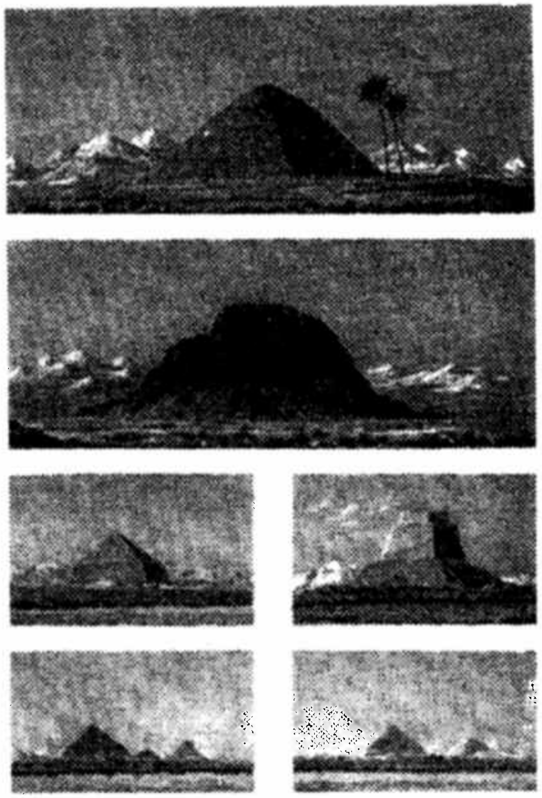

Fig. 22. The pyramids of the Old Kingdom, prior to the beginning of construction on the plateau of Giza. The Bent Pyramid and the other important pyramids at Darshur and Medum are shown.

so closely to the surrounding rockscapes as to be indistinguishable from them when viewed from afar. The complex of mud-brick dwellings and buildings, including the Great Mosque, at Timbuktu, again, seem to merge with the dry, dun-colored, Sahelian landscape that surrounds them.

Architecture, or for that matter art, as the *personal* or *individual* expression of the architect or artist is a concept alien to African thinking. With one exception, we do not know the name of a single pyramid architect in the Nile Valley.[1] The same rule applies to architectural constructions in Zimbabwe and Songhay. Only rarely do we find the African equivalents of Frank Lloyd Wright, Christopher Wren, or Le Corbusier; that is to say, architects whose distinctive style was translated into *individual* fame. Anonymity was

[1] This individual was none other than Imhotep himself, designer and builder of the Step Pyramid at Sakkara, whose name comes down as the "author" of this temple complex. Occasionally, favored architects of some of the non-pyramidal temples such as Senmut, builder of Hatshepsut's temple at Deir-el Bahari, were allowed to record their architectural accomplishments.

the rule; credit invariably went to the monarch who commissioned the project instead of the builder. The architect was recreating, as impeccably as possible, a divine ideal; he became the medium or conduit through which divine creative forces operated. His creation, veritably, was not his own. The king or pharaoh, however, could take credit because he partook of divinity as its visible representative on earth. Thus, the king, through his commission, was activating the divine will, realized through the technical skill and genius of the architect/artist.

The Pyramid: Divine Geometry in Stone

There is no geometric shape so completely identifiable with a single country as the pyramid is with Egypt. The ancient Egyptian name for the pyramid was *mer*, and therefore seems to have derived one of its names, *Ta-Meri*, meaning "Land of the Pyramid," from it. The mere sight of a pyramidal shape instantly calls Egypt to mind. As already mentioned, the Egyptians did not in any strict sense "invent" the pyramid; nature did that. But from early in its history, the master builders of the Old Kingdom appropriated the pyramid form and the pyramid became the architectural (and geometric) emblem of everything great and sublime in Egypt. It still is.

The stark, severely aesthetic symmetry of the pyramid embodied several mythic and symbolic functions. It was the stylized image of the primeval mound, rising from the formless void of *Nun*, giving the Demi-Urge a place to stand. It was solar geometry in stone, the pinnacle representing the source of the sun rays that fanned out toward earth in a "pyramidal" configuration. It was the architectural image of the Sacred 7, that is, the 3 upon 4 with four triangles conjoined on a square base. But as we shall see, the Great Pyramid in particular exhibited innumerable technical properties that show that it, like most features of Nile Valley science and technology, subserved functions that were at once empirical, theoretical, symbolic, and spiritual.

Pyramid literature is voluminous and since the middle of the last century has constituted a special discipline-within-a-discipline. In truth, most Egyptologists have eschewed pyramid studies, allegedly because of the bad name given to "pyramidology" by enthusiastic amateurs who devoted whole lifetimes to measuring and studying the Great Pyramid to prove or confirm, among other things, Biblical prophecies. But in truth, this is merely a smokescreen. Highly qualified technicians and mensurists have studied every inch of the Great Pyramid and have published findings that orthodox Egyptology finds impossible to credit, not because the findings are in error but because acceptance means the complete overhaul of history.

William Flinders Petrie, who practically created modern Egyptology, making him the "spiritual father" of contemporary Egyptologists, was one of the more celebrated of the pyramid mensurists. But his semi-legendary standing

among Egyptologists has not prevented his monograph on the pyramids from languishing in quasi-obscurity—except in one instance. Petrie's exacting measurements apparently refuted the previous findings of Charles Piazzi Smyth that one of the units of measure present in the pyramid structure is the "pyramid inch." Academic Egyptologists had scoffed at the "pyramid inch," especially because Smyth was one of the most insistent of the evangelists attempting to explain the building of the pyramid by Biblical inspiration. There was mass relief among Egyptologists when Petrie published his refutation for they then felt at liberty to discard *all* of Piazzi Smyth's pyramid work, even the considerable amount that was actually *confirmed* by Petrie's measurements.

Biblical prophecy aside, an acceptance of even a portion of the conclusions carefully amassed after more than a century of work would mean that our current notions of how and where advanced science and technology emerged bear no relation to historical reality. Indeed, we would be compelled to admit that, in some respects, the vaunted science and technology of modern times has not *yet* risen to the level of the ancient pyramid-builders. For those who prefer to insist that the Great Pyramid was merely an overgrown mausoleum, it is essential to ignore or dismiss pyramid studies.

It is the contention here that the various pyramid forms were inspired by natural formations that can be seen to best advantage in the region surrounding Abu Simbel. The conventional wisdom regarding the evolution of the pyramid commences with the *mastabas* (whose forms are also very abundant in the desert near Abu Simbel) which, in ascending layers, progressed to the true pyramidal form. This reasoning is sound enough, particularly when contemplating the earliest pyramid, the first great edifice in stone ever created by human hands, the Step Pyramid of Sakkara.

The mastaba became the first above-ground Old Kingdom tomb created. Simply described, mastabas were rectangular, single-story mud-brick structures with sloping sides and a flat top. They are called mastabas—the word coming from Arabic meaning "bench"—because when Napoleon's savants first caught site of them they were reminded of the benches used by the contemporary Egyptians. There are a profusion of remains of mastabas sitting in regular rows at Sakkara but these are mostly restored versions.[2] Virtually none of the superstructures of the original mastabas have survived. However, the underground portions have preserved markedly well and the walls are filled with drawings and paintings of geometrical design. From the layout of these interior portions, it has been possible to accurately reconstruct the mastabas as they must have originally appeared.

The mastabas ranged from 150 to 250 feet in length and surrounding the

[2] For a short but informative description of mastabas, consult John Anthony West's *The Traveller's Key to Ancient Egypt*, London: Harrap Columbus, 1987, p. 8.

central burial chamber within were smaller chambers to hold funeral offerings. A great deal about the state and condition of early Egyptian civilization can be gleaned from the large aggregation of varied artifacts—metal tools, unusual stone vases, fragments of tablets, and clay jar seals—that have been recovered from the mastaba-tombs. It is thought that the early rulers themselves lived in mastaba-like, mud-brick palaces and it is a curious fact that in all the 4,000-year history of dynastic Egypt, precious little remains of royal dwellings. Stone was used *only* to build tombs and sacred buildings, virtually never for the domiciles of mere mortals, not even for pharaohs.

It was not until the 3rd Dynasty, circa 3,500 B.C., that stone was put into architectural use on a grand scale. However that decision was arrived at, the initial result conveyed the impression that the Egyptians had been building in stone for ages. There is a conceit among many commentators—though the evidence, carefully considered, is clearly against it—that Egypt's dynastic civilization emerged on the world stage suddenly and ready-made, without clear-cut antecedents. *Deus ex machina*, as it were, ancient Egyptian civilization just appears. Though such an explanation is a distortion of the record, it has to be wondered how the ancient stone-builders architecturally achieved such supreme mastery of form and function on the first try.[3] Taken as a whole, John A. West is utterly correct in his assertion that there is no architectural edifice anywhere outside of Egypt to surpass Djoser's temple and funerary complex at Sakkara. Even within Egypt, the only true competitor is the Great Pyramid which represents an unsurpassed technical *tour de force*.

The step pyramid itself is unmistakably an elaboration of the mastaba-form (see Plate 13). One of the reasons why the structure is so unusual to study is that the original plan was revised during the course of construction at least four times at no apparent disadvantage to the final result. The original mastaba structure was about 69 square yards in area, encased in smooth white limestone above a square pit. Three additional terraces were superimposed on the base mastaba which itself was extended outward so that it encompassed a rectangular area of more than 14,000 square yards. Finally, the height of the entire edifice was raised by super-adding two more stepped terraces, giving six in all, the whole exterior lined, as originally, with fine white limestone. When completed, the Step Pyramid rose to a height of 197 feet and its slope angle was 72° 30'.

One of the best recent descriptions of the method of construction for the Step Pyramid was written by the late Peter Hodges, himself a master-builder.[4]

[3] John Anthony West points out that the hand of master stone masons is evident in some of the earlier mastabas at Sakkara but there simply was no stone-working on the scale evident in Djoser's funerary complex. One other possible clue comes from the revised age of the Sphinx which, if it holds up, does mean that large-scale (sculptural) stone-working prior to the 3rd Dynasty had occurred.

[4] Hodges P, *How the Pyramids Were Built*, edited by Julian Keable, Longmead, Shaftesbury, Dorset: Element Books Ltd., 1989.

In fact, Hodges preferred to call step pyramids "buttress" pyramids which, in his view, was more descriptive of the manner of their construction. The "true" pyramids, like those at Giza, he referred to as "coursed" pyramids because they were built up by laying squared blocks on level courses. By contradistinction, the buttress method could be characterized this way: " . . . the builders were doing no more than building walls, as their experience had taught them, but leaning them together so as to stabilise a mound."[5]

Buttress or step pyramids consisted of either six or seven concentric layers with the exposed faces limited to 30 feet in height. Stones in the lower layers weighed up to one and a half tons; in the upper layers, one-half ton. To begin, a center square and the concentric buttress lines were carefully outlined on a leveled area and then the actual construction would commence with the center core up to about chest height, according to Hodges. At that point work would begin on the first buttress that would serve as a stepping stone allowing the center to be continued upward to the prescribed height. Additional buttresses would be constructed around the inner ones and the first butresses or steps to actually be completed would be the outer two. After they had been raised to a certain height, scaffolds and/or building steps would be put in place to allow the building stones to be levered into position as the inner terraces were raised in height. The method employed made the most efficient use of the structure itself to economize on time and effort: "Every builder wants to gain as much height as possible before he has to add something temporary to his structure, such as a scaffold or a ramp."[6]

The pyramid itself is striking enough but there is a more powerful impression conveyed by the overall architectural ensemble that includes the forecourt on the south side of the pyramid, the entrance temple at its south end, and the massive wall, now almost entirely in ruins, enclosing the whole complex. The entrance temple is simply an amazing structure whose rectilinear design shows a cleanness of line with a refinement and grace of conception that became the hallmark of Old Kingdom architecture. The aesthetic perfection elicited by the elegant simplicity of Old Kingdom architecture, first realized at Sakkara, was never achieved again in Egypt and it is impossible not to admire the uncluttered genius of the architect.

The inside of the entrance temple is as admirable as the external formations. Here, for the first time in history, the "Doric"—some call it "proto-Doric"—column was erected. This architectural feature, the pride of the Parthenon, is no more Greek than the pyramid. We have already pointed out that, architecturally, the Egyptians' inspiration derived from the myriad natural forms surrounding them. These columns were explicitly modeled after papyrus reeds tied in a bundle. The columns in the entrance temple are not free-standing; a buttress attaches each of them to the wall.

[5] Ibid., p. 71.
[6] Ibid., p.. 66.

There is some quibbling about whether these marvelous columns in the entrance temple are truly "Doric" in style because they are "fasiculated" rather than "fluted,"[7] but there is no such nitpicking about the columns in the southern building attached to the entrance temple. So characteristically "Doric" are these that they admit of but one conclusion: the Greeks simply lifted this columnar style from Egypt (see Plate 14). And, many 19th and 20th century public buildings in Europe and America were done in a "neo-classic" style, prominently featuring the Doric column. Thus, we have the abiding paradox of the modern age: the more a Grecian style is striven for, the more are African-derived forms appropriated.

With the single exception of the Great Pyramid, the various pyramid structures of the Old Kingdom were royal tombs. This, however, did not prevent them serving other functions as well. One of the most successful of the pyramid surveyors, Moses B. Cotsworth, came to the conclusion that the terraced or stepped pyramid structure was devised to raise an obelisk higher off the ground so that it could cast a longer shadow.[8] Such an elongated shadow created a more precise sundial that enabled the ancients to measure the year more exactly. One generally finds, extending from the base of such a pyramid, a smooth, level court onto which the obelisk throws its shadow at noon throughout the year. As we have seen, a level, spacious, rectangular court extends southward from the base of the Step Pyramid at Sakkara. It is usually avowed that purely ceremonial and ritual functions were held on this court, but that does not rule out the distinct possibility that the part adjacent to the pyramid would have been constructed so that the shadow of the obelisk, functioning as a sun-dial, could be measured and followed throughout the year. Cotsworth also expressed the opinion that the evolution to the true pyramid form evident in the 3rd and 4th dynasties, culminating in the construction of Great Pyramid, was dictated by calendrical considerations:

> According to Cotsworth, the optimum design turned out to be the solidified Pyramid of Cheops, with its slope set for a particular latitude to swallow the equinoctal shadow. Once this method of establishing the precise length of the year had been found . . . there was no further need for enormous pyramids.[9]

Djoser's Step Pyramid temple complex at Sakkara, conceived, designed, and realized by the incomparable genius of the architect and polymath Imhotep, was humanity's first great architectural triumph. It established architectural forms, styles, and canons still in use today. The practical build-

[7] Ibid., p. 155.
[8] Cited by Tompkins P, *Secrets of the Great Pyramid*, New York: Harper and Row Publishers, 1971, p. 126. In this author's opinion Tompkins' book is simply the best compilation there is of the history of "pyramidology." Few books reveal as much about the exact sciences of ancient Egypt as this one.
[9] Ibid., p. 127.

ing technique and masonry evident in the entrance temple were never surpassed, though, as we have said, they were realized on a grander scale in the Great Pyramid at Giza. Furthermore, it is not unreasonable to suppose, after Cotsworth, that, along with its funerary function, the Step Pyramid furnished a platform to support an obeliskoid sundial, projecting its shadow on the southern court to provide a measure of the seasons. It is also pertinent to note that the famous Babylonian ziggurats were Mesopotamian versions of the Step Pyramid and that the form reappeared in the Meso-American pyramidal temples.[10]

Chronologically, the next important pyramid was the one constructed at Medum, 30 miles south of Sakkara, toward the end of the 3rd or near the beginning of the 4th Dynasty. Like Imhotep's Step Pyramid, Medum shows changes in ground plan as the work was being executed. It, too, developed from the basic mastaba form and was originally planned as a seven-tiered structure. After completion, it was decided to add an eighth terrace, which was done, then yet another decision was made to fill in the terrace spaces to complete a "true" pyramid, cased like all the pyramids in fine white limestone. At an undetermined later time, perhaps during the 19th dynasty, some of the outer casing stones were removed or extruded on their own, causing the outer packing and casing to fall away, leaving the original stepped core intact. Even today, it stands in the desert, a stepped tower surrounded by a huge agglomeration of rubble. It represents the only architectural "failure" of the Old Kingdom but it illustrates the step-by-step process by which the mastaba form, progressing through the terraced pyramid form, evolved gradually into the true pyramid. Moreover, there are those, like Peter Hodges, who think that the masonry of the Medum Pyramid, with facing stones perfectly laid and jointed and the external angles of the structure as precise and even as anything done today, represented an advance over the megalithic masonry of the Step Pyramid at Sakkara.[11] Thus, if it's a "failure," it is one that pushed Nilotic building technique forward.

The triumph of several generations of architectural experimentation, leading to the creation of true functioning pyramids, was finally achieved at the beginning of the 4th Dynasty, in the reign of Seneferu. This pharaoh, the founder of the dynasty, commissioned two pyramids to be built during his lifetime at Dashur, five miles south of Sakkara: the so-called Red Pyramid and

[10] See Tompkins P, *Mysteries of the Mexican Pyramids*, New York: Harper & Row Publishers, 1976, for an absorbing account of the history of Mesoamerican pyramidology. Like the Nile Valley pyramids, much scientific data was encoded in the structures of these edifices. The famous Sun Pyramid in Mexico City was constructed of six terraces and in this and other ways seems a replica of the Step Pyramid of Sakkara.

[11] Hodges, op. cit., p. 57. It is perhaps worth pointing out that the incredibly fine masonry of the entrance temple to Djoser's Pyramid is superior to that of the pyramid itself. This was the world's first attempt at construction of such a large stone edifice. The problems of translating the fine masonry of the temple complex to the pyramid structure itself would be worked out in succeeding generations.

the Bent Pyramid. The Bent Pyramid is so named because about halfway through the construction, the angle or slope of the pyramid was changed. This pyramid starts off at an inclination of 53°27' but, halfway to the pinnacle, the angle of inclination changes to 43°27'44". In every other respect, the masonry is just about perfect. There has been much speculation about the reason behind this shift in slope but no explanation has proved satisfactory.

With the Bent Pyramid, these Nilotic builders revealed a mastery of technique that would enable them to build structures on such a grand scale that their like would never be seen again. As Hodges described, the stones are squared and bonded together horizontally on successive courses.[12] Thus, the core stones of the pyramid could be bonded from the center to the faces. It is this method of bonding, in contrast to buttressing, that confers stability on this and others of the massive "coursed" or "true" pyramids.

Its sister pyramid, the Red Pyramid, in view of the subsequent collapse of the pyramidal exterior at Medum, carries the distinction of being the first true pyramid, one hardly less massive than the Great Pyramid. John Anthony West correctly points out that if Sneferu commissioned these two pyramids, then he presided over a construction effort that, in a period of 24 years, involved quarrying, transporting, and dressing *nine million tons of stone*![13] This exceeds the tonnage of the Great Pyramid by $2^1/_2$ million. Taken together, then, the sheer engineering and logistical effort behind the construction of Sneferu's two pyramids unfolded on a scale larger than that of the fabled Great Pyramid. It means that the necessary technical skill, knowledge, and logistical organization for such immense projects had already been thoroughly mastered by the time the building of the Great Pyramid commenced.

Before entering into a discussion of the Great Pyramid, it is worth asking the question, why build so many pyramids? By the time Egyptian pyramid-building was done at the end of the Middle Kingdom, a line of pyramids extended 94 miles south from Giza. The encyclopedic Peter Tompkins furnishes a clue:

> For right-angled trigonometry, the Australian engineer [R.T. Ballard] realized, true straight lines could be extended from the pyramids in given directions by direct observation, without the aid of other instruments, and that with the simplest of instruments, angles could be exactly observed from any point. . . . In a short time *anyone* might construct a table for himself answering to every degree or so in the circumference of a circle for which only forty or fifty triangles are required. . . . Such primary triangulation would be useful to men of almost every trade and profession in which tools or instruments were used.[14]

Taken with the pyramids of Giza, the string of pyramids extending southward meant that, by the method of triangulation, whole sections of the coun-

[12] Ibid., pp. 60–2.

[13] West, op. cit., p. 199.

[14] Tompkins, op. cit., p. 120.

try could be precisely measured and surveyed at any time. This capability was essential in a country where annual floods erased field boundaries.

The Great Pyramid: The Measure of the World

Which brings us to the Great Pyramid. There is simply no arguing that it is the most stupendous structure ever raised by human hands. It has never failed to strike observers with an overpowering awe and it has embroiled the imaginations of better than 150 human generations. Today, the fascination, indeed obession, with the Great Pyramid continues unabated, spawning a huge literature. Pyramid investigators fall into two camps: (1) orthodox academics who insist it is a tomb and nothing but; (2) a substantial coterie of scientists and surveyors who insist with equal adamancy that it is an extraordinary architectural and engineering marvel encoding all manner of mathematical, astronomical, and geodetic data.

Herodotus supplied the most complete classical description of the building of the Great Pyramid, relating that it took 30 years to build, employing shifts of 100,000 laborers working three months at a time. Herodotus informs us that the great causeway, over which presumably the blocks were moved as the edifice was being built, took 10 of those 30 years to build. The melodramatic 19th and 20th century imaginations—embellished repeatedly by Hollywood—painted lurid tableaus of ant-like hordes of slaves laboring and dying under the lash merely to create an oversized monument to the outsized ego of pharaoh. More sober minds have prevailed recently, particularly as the workmen's quarters surrounding the plateau of Giza have lately been unearthed, showing the laborers to have been *professional* artisans, masons, and stoneworkers who were full-fledged citizens of the country. Concerning this gargantuan construction effort, Julian Keable has this to say: "Subdued and fearful gangs of slaves have no place in such a scene—but a respect for repetitive manual work certainly has, a respect which is born out of the evident orderliness of the building operation, as well as its scale."[15] Furthermore, as Somers Clarke and R. Engelbach remarked, "We cannot help admitting that they were perhaps the best organizers of human labour the world has ever seen, and their method of carrying out a task always appears to be the most efficient and economical."[16]

The Great Pyramid rises to a height of 481 feet and 3 inches, composed, when it was completely intact, of 210 courses of masonry.[17] The angle of

[15] Keable J, "Foreward" to Peter Hodges' *How the Pyramids Were Built*, pp. ix-x.

[16] Clarke S and Engelbach R, *Ancient Egyptian Construction and Architecture*, New York: Dover Publications Inc., 1990, p. 3.

[17] There are numerous works available detailing the myriad measurements and dimensions of the Great Pyramid. Our discussion draws from the previously cited works by Petrie, Piazzi Smyth, and Tompkins in addition to A. Pochan's *Mysteries of the Great Pyramids*, New York: Avon Books, 1978.

the slope of each of the faces, determined from the remnants of casing on the northern base, was 51°51'. It is situated nearly 200 feet above sea level and nearly 130 feet above the ancient Nile flood crest. The estimate of the number of stones, cut and dressed, ranges from 2.3 to 2.8 million. The average weight of the interior blocks was $2^1/_2$ tons, with a range of 1 to 7 tons. However, some of the casing stones at the base weigh as much as 16 tons and granite blocks in the King's Chamber weigh 100 tons. More than 13 billion pounds of masonry went into the construction of the intact Pyramid, enough to build a wall four feet high two-thirds of the way around the globe.

The pyramid was built mostly of limestone cut from surrounding quarries, though the interior rooms such as the King's Chamber were constructed entirely of granite floated 500 miles down the Nile from Aswan. The outer casing, as for all Old Kingdom pyramids, was made entirely of fine white limestone that left a true and even pyramidal shape as precisely realized as any modern measuring apparatus could have achieved. Few of the casing stones remain, but those that do show a level of building technique that defies the imagination. The stones are fit together so evenly and finely that the joints would hardly admit a strand of hair between them (see Fig. 23). Never since has such perfection of masonry been seen:

> Though the stones were brought as close as $^1/_{500}$ inch, or, in fact, into contact, and the mean opening of the joint was but $^1/_{50}$ inch, yet the builders managed to fill the joint with cement, despite the great area of it, and the weight of the stone to be moved—some 16 tons. To merely place such stones in exact contact at the sides would be careful work; but to do so with cement in the joint seems almost impossible.[18]

Each side of the base of the pyramid measures 755 feet, 8 inches with an average error of $^1/_{10,000}$th from straightness. This incredible accuracy moved Flinders Petrie to say that here was precision such that only an optician could obtain, but this compares work on a scale of acres to that on a scale of millimeters.[19] The pyramid shape was the best one available to the ancient builders that permitted them to raise these edifices to such commanding heights using the least amount of material.[20]

The thorniest issue of pyramid studies concerns how the builders actually performed the task of raising such a massive structure using $2^1/_2$ million stone blocks. Even today, no one knows for sure, a climate of uncertainty that has given rise to an endless variety of fantastic speculations. The safest—and best attested—route is to assume that the builders of that time used only such instruments as were known to be available to them. With this

[18] Petrie WMF, *The Pyramids and Temples of Gizа*, London: Histories and Mysteries of Man Ltd., 1990, p. 13.

[19] Ibid.

[20] Hodges, op. cit., pp. 2, 7.

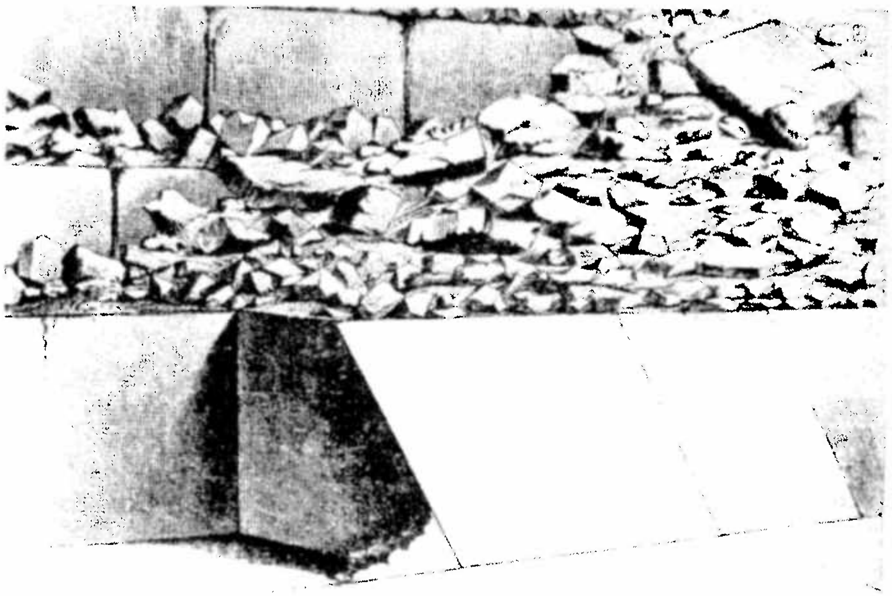

Fig. 23. Remnant of the original casing stone of the Great Pyramid. Intact, the entire pyramid would have been covered with such casing of white limestone. The joints between the stones were so fine as to be barely visible.

premise firmly in hand, the possible building methods can be pared down to two or three choices. The theory favored by most academic Egyptologists involves the erection of ramps to move the stones into place by means of sleds and rollers. The other theory of consequence, one first described by Herodotus, involves the use of levering mechanisms.

Peter Hodges, in his book *How the Pyramids Were Built*, attacked the problem from the point of view of a builder who, with the available tools, would have had to master the challenges of moving $2^1/_2$ million colossal stones to an increasing height that ultimately topped out at 40 storeys. What the Egyptians did *not* employ were wheeled vehicles or pulleys.[21] Moreover, Hodges pointed out that to have built ramps at a low enough gradient to allow stones to be pushed upward on a rising pyramid would have involved construction using *three times as much material as the pyramid itself*. All authorities agree that the Great Pyramid was completed within a generation (30 years); there is equal agreement that the Egyptians were the ancient world's greatest efficiency experts. These two facts alone make the ramp *modus operandi* implausible.

[21] In this the Egyptians were the same as the Incas who also raised great constructions of large, evenly fitted stones without the wheel. It is probably a mistake to assume that the Egyptians did not *know* of the wheel; for reasons that are obscure to us, they simply chose not to make use of it until the 18th Dynasty.

Having considered the problem, Hodges accepted the explanation of Herodotus, that the stones were levered into place, going so far as to say: "We should be able to recognise that such a method [levering] was the only one which could have been used to handle stones of such weight and in such numbers."[22]

The levering is best understood by thinking of the mechanism involved in jacking up a car.[23] In the absence of wheels and pulleys, levering enables the smallest amount of manpower to be used to lift the greatest amount of weight up a vertical height. As Hodges put it, one man can do the work of 12. Furthermore, levering precludes the use of ramps or scaffolding that would clutter up the work space. As Hodges noted, the only things the workmen would need to remove at the end of the project would be their own tools. There would be no ramps or scaffolds to dismantle or ramp material to dispose of. This "autostatic" method was also more efficient than the techniques used in raising the early step or buttress pyramids because of economies in time, labor, and material. Timber packing would have been inserted beneath the stone after each "jack" to lift it ever higher. By this method, a well-practiced team of laborers could raise a $2^1/_2$ ton stone step by step halfway up the pyramid within a day.

The task of raising and accurately setting in place hundreds of heavy stone blocks a day was itself a formidable challenge, but the pyramid-builders faced more subtle and refined tests of their ingenuity, care, and attention to detail. First, the ground surface had to be precisely leveled, achieved by creating small canals upon the construction site and filling them with water. Using a level water surface is still the most accurate method for ensuring a true horizontal plane. A similar use of water could be adapted on each course to ensure an evenly planar surface. Furthermore, the pyramid had to sit, course by course (210 in all) exactly true upon a perfectly square base, while the apex, at a height of nearly 500 feet, had to be set over the exact center of the base. The builders did not have a point 481+ feet high to aim at; they had to maintain the exact squareness and trueness of each course only by reference to the one below it. Thus, if there was even a small error in the setting out and laying of one concourse, it would magnify itself to eventually introduce a "twist" in the finished edifice.[24]

The most effective and practical method of creating consistently square and true ascending concourses would have been by raising the angles or corners first then laying in evenly the squared blocks. Continual testing of

[22] Hodges, op. cit., p. 19.
[23] Other authorities besides Peter Hodges accepted the levering explanation. Flinders Petrie, Somers Clarke, and R. Engelbach were also convinced that the lever system is the one that accounts for most of the facts known about pyramid construction.
[24] Clarke and Engelbach, op. cit., p. 125.

squareness is achieved by measuring the diagonals.[25] Through use of finely-calibrated calipers, it is possible even to test "cubeness" by measuring diagonals. In this stupendous structure, these Nilotic builders avoided even the slightest twist; clearly they had achieved a refinement of measurement equalling that of the most sensitive modern instruments. In the words of Peter Hodges: "The pyramid builders understood sighting, planes, squares, diagonals, and parallels, and that these skills could be enlarged for use on the building sites of the pyramids (see Fig. 24).[26] Hodges further insisted that the builders were so confident of their skill, so thoroughly in command of their techniques, that they knew, before they laid the first stone, that they could (and would) achieve a true and accurate pyramid shape, though several decades, millions of blocks of stone, and hundreds of thousands of masons, craftsmen, and laborers would be invested in the structure's completion.[27]

Finally, Hodges offered one of the more novel explanations of how the pyramids of Giza were finally brought to their characteristic shape. At the end of construction, the pyramids had a terraced look very similar to that of the step pyramids. Hodges suggested that the ledges or steps were then trimmed away by chisel from the top down to produce the final smooth pyramidal form.[28] Hodges admitted, however, that this explanation needed further verification.

The sides of the Great Pyramid are oriented perfectly to the four cardinal points. The first 19th-century astronomers to consider the problem of the pyramid's orientation, Sir John Herschel, Charles Piazzi Smith, and Richard A. Proctor, decided that the ancient builders had used the north pole star to correctly orient the pyramid.[29] The star closest to the polar position at the time the pyramid was built was α-Draconis, which at its closest point was 3°43' from the celestial pole. It was surmised that the Descending Passage, whose entrance was originally situated on the 16th course before the outside was dismantled, was used to align the northern face of the Pyramid to α-Draconis, and this accounts for the extraordinary straightness of the Passage that Petrie discovered after surveying it. In order for the Descending Passage to have been pointed straight at α-Draconis at its closest position to the North Pole, it would have to have been inclined at an angle of 26°17' and this is the *exact* angle of inclination of the Passage (see Fig. 25). Knowing this, we can determine the date for the construction of the Descending Passage, and therefore arrive at a close approximation of the date of completion of the pyramid itself.

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[25] This discussion sheds light on the famous problem of the "double remen," obtained by calculating the diagonal of a square. It also shows how all "theoretical" Nilotic sciences were thoroughly grounded in practical, "everyday" realities.
[26] Hodges, op. cit., p. 36.
[27] Ibid., p. 33.
[28] Ibid., p. 91.
[29] See Tompkins, op. cit., pp. 149–50; also Piazzi Smyth C, *The Great Pyramid*, New York: Bell Publishing Co., 1978.

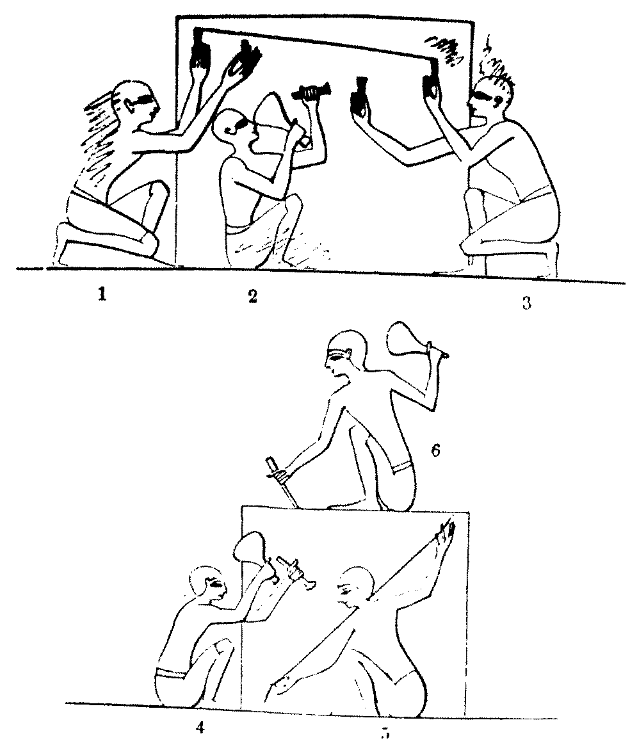

Fig. 24. *Upper register:* Leveling a large building stone using chisel and mallet. *Lower register:* Squaring the stone by means of the diagonal. Here is the practical application of the problem of the "double remen."

Alpha-Draconis occupied the position of 3°43' from the polar position twice in the last 5,500 years: the first time was 3,340 B.C. and the second time, 2,170 B.C. The second date, being of Middle Kingdom vintage, is entirely too late for an Old Kingdom structure like the Great Pyramid. Therefore, we are driven to conclude, on the basis of astronomical data, that the Descending Passage was excavated in alignment to α-Draconis 3,340 B.C. and the entire superstructure of the Pyramid was completed within 20 years after that. This tacks on about 800 years to the conventional age assigned to the Great Pyramid.

It is worth turning briefly to a consideration of some of the internal features of the Great Pyramid. The Descending Passage leads downward from the true entrance at an angle of 26°17' for a little over 69 feet to the entrance of the Ascending Passage, reflecting away from the Descending Passage and inclining upward toward the center of the pyramid at precisely the same angle of 26°17'. However, the Descending Passage continues down-

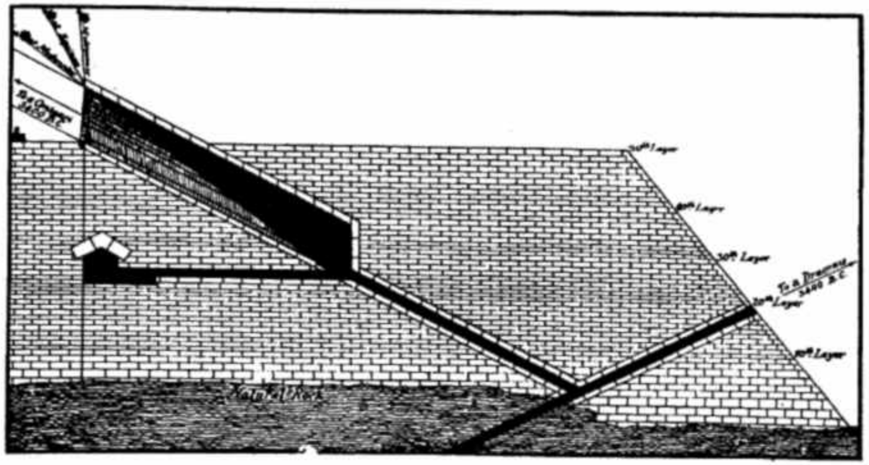

Fig. 25. Cross-sectional diagram of the Great Pyramid showing the alignment of the Descending Passage to a-Draconis 3,340 BC. The orientation of the Grand Gallery to the southern stars is also depicted.

ward past the Ascending Passage, narrowing to dimensions of 3'6" wide and 3'11" high, requiring anyone proceeding downward to bend forward at the waist for another 276 feet, giving 345 feet for the entire length of the Passage. At the end lies a subterranean chamber some 11 feet high whose function, ritualistic or otherwise, remains a complete mystery.

At the entrance to the Ascending Passage, a prospective entrant is confronted by a granite plug—actually three in all, lined up one behind the other—obstructing the opening to the Passage. To obtain admittance to the Passage requires crawling through a tunnel dug out much later around the three plugs to obtain ingress into the Passage. Its height is something over 4'4" which prevents most adults from climbing it standing erect.

At 129 feet from its opening into the Descending Passage, the Ascending Passage levels out and opens onto two other passages: a horizontal one, leading to the Queen's Chamber, and a continuation of the Ascending Passage, called the Grand Gallery, that is spacious enough to allow any adult-size individual to continue climbing erect. At the end of 157 feet, at the level of the 50th concourse, the Grand Gallery debouches into the King's Chamber.

The King's Chamber is unquestionably the most intriguing of the internal features of the pyramid for it is the only part of the Pyramid that is constructed entirely of granite blocks, some weighing more than 100 tons. Also, inside the King's Chamber is located the granite coffer, the only such accoutrement in the entire pyramid. It is too wide to have fitted through the entrance to the Chamber and is therefore thought to have been fashioned in place as the Chamber itself was being built.

Though it is evident that, to a large extent, symbolico-ritual considerations dictated their construction, the exact significance of these corridors, passageways, and chambers is still obscure. What is entirely lacking are *any* of the inscriptions, scenes, or paraphenalia associated with Egyptian mortuary practices. If the Great Pyramid was a tomb, it could not have been designed for mortal remains, though other pyramids undoubtedly were. That it served some grand, occult, initiatic purpose—along with its empirico-scientific functions—seems beyond question. Since initiation always involves symbolic rites of death, burial, and resurrection, it is only in this sense that the pyramid can be deemed a tomb.

It is time now to delve into the mathematic, scientific, and geodetic facts incorporated into the Great Pyramid's structure. As we have intimated, this topic has called forth reams of print, generating heated debate for and against acceptance of the ancient Egyptians' command of advanced scientific methods and concepts.

A word about the professional doubters—the "anti-pyramidologists"—whose numbers are legion. Certain mathematical "enigmas" such as the encoding of the π and ϕ constants into the dimensions of the pyramid have been repeatedly demonstrated, confirmed, and re-confirmed by scientific surveys from all over the world. Not being able to specifically refute these data, the skeptics have taken to explaining away the results by constantly invoking the threadbare cliche of "coincidence." Coincidence is the standard fall-back position of those who cannot understand or refuse to accept facts that do not reconcile with their entrenched academic postures or prejudices. It is a way of explaining away inconvenient realities without actually having to disprove them. Thus, the invocation of "coincidence" means that the skeptic can't believe but he or she can't disprove either; the label of "coincidence" permits the skeptic to deny the "enigmas" academic currency. In academic parlance, in order for a theory, demonstration, or interpretation to be refuted, it must first be "falsified." One searches the literature in vain for a single academically rigorous falsification of the thesis that, built into the structure of the Great Pyramid, is a wealth of scientific data revealing the spirit of a civilization not less advanced than the modern one. This being so, the derision of the professional skeptics need not be taken seriously.

We have already seen that the Great Pyramid was aligned and oriented according to specific astronomical observations and measurements, and indeed it is clear that it was the technical and scientific requirements of the ancient Nile Valley astronomers that dictated the construction of parts of the Great Pyramid. There have been specific references to the astronomical functions of the pyramid by ancient Greek and Arabic writers.[30] In fact the Neo-Platonist Proclus tells us that the pyramid was used as an observatory prior

[30] Tompkins, op. cit., p. 147.

to its completion.[31] Now for making accurate observations of the movements of the heavenly bodies, it is essential to establish a heavenly *meridian* corresponding to an earthly one. A meridian is a great circle passing throught the poles of the heavenly sphere and the zenith of a fixed point on earth. Seen from earth, the sun, stars, moon, and planets appear to move in a circle around the earth and an exact earthly meridian allows the projection of a true meridian into the heavens (and vice-versa). Careful observation will allow a trained sky-watcher to detect the exact moment when any of the heavenly bodies move across or "transit" the meridian. This allows the observer to determine the body's rate of movement in its apparent circular orbit in the sky, providing the basis for charting and mapping the heavens, and, incidentally, charting and mapping the earth as well.

In Chapter 3, we made mention of the technique of laying and orienting the foundations of any sacred or official building in ancient Egypt by "stretching the cord." Part of this ceremony of stretching the cord included observing the culmination of a designated circumpolar star[32] to determine the north-south direction to be marked out precisely on the ground. The 19th-century astronomer Richard A. Proctor concluded that the ancient pyramid builders, having established a true earthly meridian, continued to use the polestar of the time to establish the angle of descent of the Descending Passage.[33] As seen above, this is how the Descending Passage came to be exactly aligned with α-Draconis in 3,340 B.C.

In Proctor's view, the ingenuity of the builders allowed them to devise an elegantly simple technique for establishing the angle of inclination for the Ascending Passage toward the center of the pyramid:

> . . . says Proctor, the builders hit upon the idea of creating an Ascending Passage at precisely the reflecting angle of 26°17'. By plugging the Descending Passage and filling it with water, they could reflect the polar star back up an Ascending Passage and continue to keep the passage truly aligned and the building level as it rose another score or more of courses.[34]

It is in the construction of the Ascending Passage that the original function of the Grand Gallery as the functional equivalent of a telescope comes into play. We have already seen that when the Ascending Passage reaches a level, it continues upward as the Grand Gallery, which is 28 feet in height, nearly 7 times the height of the Ascending Passage. The Ascending Passage and its continuation, the Grand Gallery, are aligned precisely to celestial

[31] Ibid.
[32] Circumpolar stars are those around either of the poles, which never set, making them ideal for orientation.
[33] Proctor RA, *The Great Pyramid*, London: Chatto & Windus, Piccadilly, 1883,pp. 78–183.
[34] Tompkins, op. cit., p. 151; see also Proctor, op. cit., pp. 118–21.

Fig. 26. Artist's rendition of the Grand Gallery as seen in Napoleon's time. The corbelled shape of the gallery is shown to good effect.

south. We have seen how this precisely southward alignment was achieved, that is, by reflecting the light of the north polestar back upward from the Descending Passage. Tompkins explains the initial function of the Grand Gallery in this way:

> Had an ancient astronomer wished for a large observation slot precisely bisected by a meridian through the north pole, so as to observe the transit of the heavenly bodies, what would he have requested of an architect? A very high slit with vertical walls, says Proctor, preferably narrower at the top, a gallery whose aperture, thanks to the reflected light of the pole star, could be designed so as to be exactly bisected by a true meridian.[35]

[35] Tompkins, op. cit., p. 152; see also Proctor, op. cit., pp. 127–8.

Considering that the construction of the pyramid was temporarily halted right at the completion of the Grand Gallery, giving any observer within it an unobstructed, clear, dry view of the southern sky along the polar meridian, the exact conditions described by the above quote are met in the Grand Gallery. As Tompkins notes, the entire southern circle of equinoctal constellations and their transits across a well-defined meridian could easily be observed. Every star in an 80° arc of the southern heaven could be observed and measured with great precision, and after repeated observations by trained observers at different levels of the Gallery over a certain span of time (perhaps a year), these ancient astronomers could have eventually developed an accurate sidereal clock. Then, when the period of observation was completed, all the sky measurements recorded, and accurate star-time developed, the builders could continue building the pyramid to completion.

Looked at in this way, it is hard to think of any other acceptable explanation for the manner in which the Grand Gallery was constructed. Concerning this, Proctor wrote: "We should find . . . in this double character of the Ascending Gallery, proof positive that it was intended for astronomical observations. *Only an astronomer would have set the architect such a problem*" (emphasis added) (see Fig. 27).[36] This interpretation fits in with verifiable data concerning the interior architecture of the pyramid, with information concerning the ancient Egyptians' formidable astronomical knowledge, and it resolves many enigmas. We have no shred of evidence suggesting that the Old Kingdom sky-watchers possessed telescopes, so the Grand Gallery, used as an observatory when it was still open to the sky, allowed them to glean the maximum celestial data from naked-eye astronomy.

What is also interesting about the Grand Gallery is that it debouches exactly at the 50th course of masonry of the pyramid, and at that storey the square platform is exactly *half* the area of the base of the pyramid (see Fig. 28).[37] Moreover, since the flat platform of this course, when it was still the truncated top of the pyramid under construction, was used to map all quadrants of the sky in preparation for the early zodiac, it is interesting to note that subsequent zodiacs, all the way into Renaissance times, took on a similar square configuration.[38] There is even a square zodiac at Denderah.

Finally, the observations made from within the Gallery and atop the platform onto which the Gallery opened would have permitted the accumulation of such data as to mathematically plot the Precession.[39] The Alexandrian as-

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[36] Proctor, op. cit., p. 132.
[37] Ibid., p. 156.
[38] Ibid.
[39] The present writer has written about the Precession in several previous publications, so just a few words will be devoted to it in this chapter. We can say that though the tools for actually calculating the Precession precisely may have been made possible by observations taken in and on the pyramid, there are indications that the phenomenon was known some 7,000 years or perhaps even 30,000 years earlier.

Fig. 27. Proctor's conception of what the Grand Gallery would have looked like when it was open to the southern heaven. Trained sky-watchers taking numerous measurements of the southern stars transiting the open aperture would have been able to determine the heavenly (and hence earthly) meridian. They would also have been able to determine the time of the star's transit, thereby measuring the speed of rotation of the vault of heaven and thus of earth itself.

tronomer Hipparchus (c. 127 B.C.) is ordinarily credited with having discovered the Precession—though the first explanation of the mechanics of the phenomenon is attributed to Newton—but a number of modern commentators avow that the Precession was known long before Hipparchus's time.[40]

Few pyramidal debates are more heated than those centered around its geodetic functions. Geodesy is that branch of applied mathematics that exactly localizes specific points and areas over large expanses of the earth's surface and determines the shape and size of the earth itself. It is, of course, closely allied with geography and both of these sciences are fundamental to the creation of accurate maps. Specifically, geodesy involves finding the correct longitude and latitude of a given place on the earth's surface. Much of the reluctance to accept the possibility of advanced geodesy in high antiquity stems from the unwillingness to admit that the whole world had been traversed and mapped ages before Columbus.

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[40] See De Santillana G and Von Dechend H, *Hamlet's Mill*, Boston: David R. Godine, 1977, for an extended discussion of ancient pre-Hipparchan knowledge of the Precession.

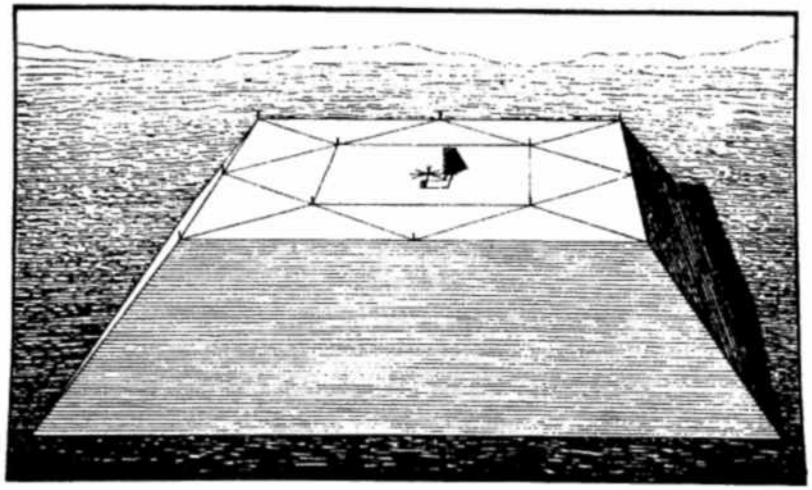

Fig. 28. The Neo-Platonist Proculus reported that the construction of the Great Pyramid was halted so the open platform could be used to make astronomical measurements. Proctor thought that the work was halted at exactly the 50th concourse whose area is exactly half the pyramid's base. The Grand Gallery terminates at and enters onto the 50th concourse.

Conventionally, it is assumed that longitude could not accurately be determined until the development of the sextant in the 18th century. However, it is *known* that Ptolemy of Alexandria, author of the famous *Almagest*, had apparently devised his own method of finding latitude and longitude, one based on astrononomical observation. Nonetheless, it is now clear, after some remarkably original research by Livio C. Stecchini, that both the Chaldeans (Babylonians) *and* the Egyptians had developed geodesy to a high level and that both cultures incorporated their knowledge in their architecture.[41] Nor is it too much to infer that Ptolemy's own work in geodesy owed considerably to his Egyptian predecessors since he was native to Alexandria.

Stecchini points out that Egypt was, in effect, re-mapped with the beginning of the dynastic period. Before that time, circa 4,000 B.C., Egypt had been divided into six zones; after that, it was divided into seven. This change may have been dictated by the need to reconcile Egypt's earthly geography with (1) the "geography" of the heavens which was septenary ("by 7's") and (2) the Egyptian harmonic scale, composed of 7 basic tones or notes. This change from the sextenary ("by 6's") to the septenary system is seen also in their units of measure. According to art historian Erik Iversen, the original

[41] See Stecchini LC, "Notes on the Relation of Ancient Measures to the Great Pyramid," Appendix to Peter Tompkins', *Secrets of the Great Pyramid*, op. cit., pp. 287-382. Stecchini was one of this century's foremost experts on ancient measures. His dense, detailed 96-page essay at the end of Tompkins' volume must eventually revamp entirely the study of ancient history.

Egyptian cubit, the "short" cubit, was one based on 24 palms. The royal cubit was created out of this one by increasing it by 7/6 to 28 palms, reflecting the change from the sextenary to the septenary system.[42] Indeed, the first two pyramids, both constructed in the 3rd Dynasty, seem to indicate this transition from the sextenary to the septenary system upon which the geography of dynastic Egypt was constructed. Imhotep's Pyramid at Sakkara, the first of the pyramids, consisted of *six* steps or terraces. The one at Medum, built within two generations of Imhotep's, consisted of *seven* steps.

The first indication that the Great Pyramid was not randomly or haphazardly placed came from Napoleon's survey team in 1800. Seeking to accurately map northern Egypt, the surveyors quickly discovered that if a meridian was projected due north through the apex of the pyramid, the Delta was bisected neatly into two equal halves by area. Moreover, a right angle extending from the junction of the pyramid's northwest and northeast diagonals, completely and neatly enclosed the western and eastern boundaries of the Delta (see Fig. 29).[43] It was impossible to believe then, as it is now, that this was a fortuitous incident and even if no further information about the Great Pyramid had been forthcoming, this finding alone would have established uncontestably the ancient Egyptians' possession of advanced geodetic knowledge.

Stecchini tells us that the ancient Egyptians used three different latitudes to identify the Tropic of Cancer,[44] which was customarily taken as the southern limit of the kingdom. Now the Great Pyramid was situated at the "perfect" latitude of 30°, signifying it as the northern boundary of the southern portion of Egypt. The geographic shape of Egypt roughly conforms to that of the lotus flower, with the "stem" comprising the narrow, fertile strip hugging the Nile as it meanders northward, beginning at the First Cataract.[45] The open "bud" of the lotus-figure is the Delta itself; thus Upper Egypt comprised 6/7 of the country by length. The northern (lower) edge of the First Cataract is situated at 24°06' north and the southern (upper) edge at 24° north. Thus,

[42] See Iversen E, *Canon and Proportions in Egyptian Art*, Warminster: Aris and Phillips Ltd., 1975, passim. Might this six-to-seven transition be the reason behind the colloquial phrase "at sixes and sevens," meaning "disordered" or "confused?"

[43] Tompkins op. cit., p. 46; Piazzi Smyth, op. cit., p. 226.

[44] The Tropics—Cancer north of the equator and Capricorn south of it—are defined as the highest and lowest limit of the sun's apparent movement on its ecliptic path. The sun's ecliptic is caused by the fact that the Earth is tilted as it revolves around the sun. On one side of the sun, the northern hemisphere is inclined to the sun; upon reaching the opposite side, the southern hemisphere is. At the summer solstice in the north (June 21) the sun is right over the Tropic of Cancer; at the winter solstice (December 21) it is right over the Tropic of Capricorn. Thus, when it is summer north of the equator it is winter south of it and vice-versa.

[45] Strictly speaking, the "First" Cataract is actually the *Sixth* Cataract because the Nile flows from south to north and the ancient Egyptians always deemed the south as the point of origin. Thus, of the six cataracts between Aswan and Khartoum, the one near Khartoum should be the first and the one at Aswan the sixth. However, we are tied to a 2,000-year convention that designates the cataract at Aswan as the "First."

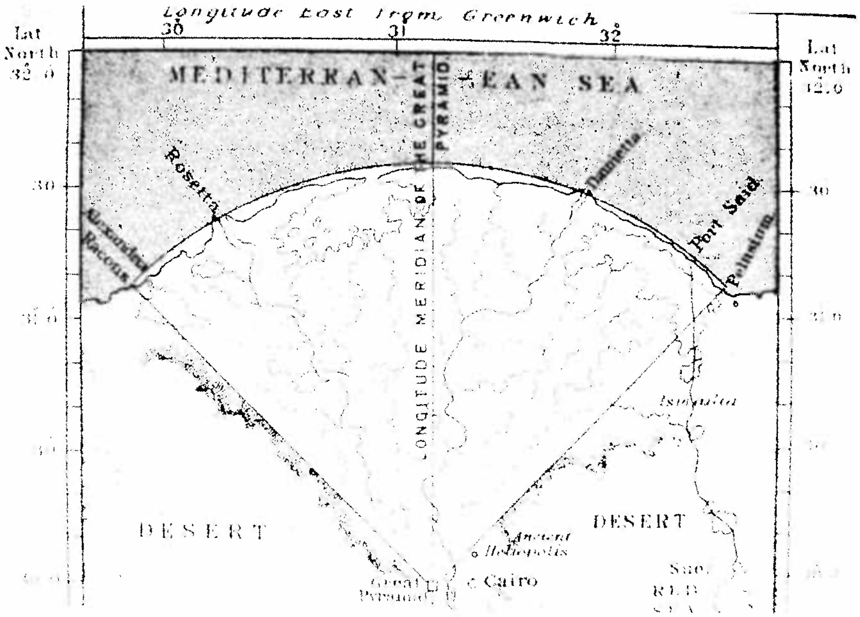

Fig. 29. Where the meridian line running through the center of the Great Pyramid crosses Egypt's Mediterranean coast, it bisects the Delta into two equal triangular sectors that can be measured by trigonometry.

the Egyptians, in order to keep the dimensions of Upper Egypt in whole number degrees, took the southern edge of the First Cataract as its southern boundary, giving Upper Egypt a dimension of 6°.

Aside from the pyramid itself, Stecchini states that there was another geodetic landmark that served as the meridian indicator bisecting the Delta, i.e., the Delta's apex at 30°06' north, geodetically 6 minutes north of the pyramid. This, too, could be considered Upper Egypt's northern limit while preserving the integrity of the 6° for the geodetic length of Upper Egypt since the southern boundary, in this instance, could be reckoned from the lower edge of the First Cataract at 24°06'.

In pre-dynastic times, the Tropic of Cancer was at or very near 24° north. Early in the dynastic period, the Tropic had shifted south to 23° 51' north and this change in the Tropic meant that there was no longer an even measure for the geodetic length of Upper Egypt based on either of the two northern landmarks: the Great Pyramid (30° N) or the Delta's apex (30°06' N). According to Stecchini, this discrepancy was resolved in a particularly ingenious way:

> The discrepancy was rationalized by considering the fact that when one follows the movement of the sun along the ecliptic by observing the shadow cast by a pointer, there must be introduced a correction of 15'. The position of the shadow is not determined by the center of the sun, but by the upper limb of the disk. The apparent diameter of the sun is about half a degree [15'].[46]

If 15' is added to the Tropic of 23°51' at the time when the sun is exactly overhead on the first day of the summer solstice, the measuring point is actually at 24°06', already indicated as one of the southern boundaries in reckoning the length of Upper Egypt. It is for this reason that Stecchini insists that the Egyptians recognized three lines of the Tropic and this was inscribed in the tableau which depicts the neters—sometimes two forms of *Hapi*, sometimes *Heru* (Horus) and *Set*—uniting Upper and Lower Egypt by knotting the papyrus, symbol of Lower Egypt, and the lotus, symbol of Upper Egypt. At the bottom of the lotus register, three short horizontal lines are inscribed which, in Stecchini's view, represent the three values of the Tropic.

The above notwithstanding, the Egyptians still rationalized the geodetic dimensions of their country based on the actual tropic of 23°51' N by building Memphis, the capital city of the Old Kingdom, precisely at 29°51' N, i.e., 6° exactly north of tropic. Indeed, every major urban cult center was built at a distance that was in some fixed ratio to the Tropic. According to Stecchini the Egyptians went to extraordinary lengths to situate their cities at even proportional distances from their major geodetic landmarks. Such considerations even motivated religious revolutions and imperial enterprises.[47]

The Egyptian prime meridian was projected through Behdet, on the Mediterranean coast, because it was the coastal point, situated at 31°14' E and 31°30'N, that was aligned exactly with the meridian points through the pyramid and the apex bisecting the Delta. Behdet was apparently a pre-dynastic geodetic center, dedicated to Horus, that gave way in the dynastic era to the slightly more southerly latitude of 31°06' as the official northern boundary of the country, giving exactly 7° between it and the southern national border at the northern edge of the First Cataract. Thus was Egypt remade according to a septenary model.

The eastern and western borders were established at the corners of the Delta 1°24' East and West of the prime meridian passing through the apex at 31°14'E. Meridians were extended southward from these east and west boundary markers to reconcile the geography of Egypt as much as possible to a rectangle. The western meridian-border of Egypt, therefore, was considered to be 29°50'E. This is, in effect, the same meridian upon which sits Alexandria, located at the western corner of the Delta at the meridian 29°54'E, providing us with a perfect explanation of why Alexander the Great

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46 Stecchini, op. cit., p. 296.

47 Thus, in Stecchini's view, the Amarma "revolution" of Akhenaten was, in part, dictated by his determination to reset the geodetic center of Egypt so as to re-establish the original pre-dynastic geodetic system. Moreover, imperial land-grabbing in lower Nubia in the Middle and New Kingdoms also may have been partly motivated by the desire to institute a new geodetic system.

chose to establish his capital in that particular location. We know that Alexander's first undertaking after driving the Persians out of Egypt was a perilous 10-day expedition to the Oasis of Siwa in the Western or Libyan Desert, sacred to Amon. There, apparently, he became installed as the new "Son of Amon" and, since we find that he scrupulously followed age-old geodetic procedure in his adopted land, we can guess that it was the priests of Amon at Siwa who guided him in choosing the location of the new imperial capital Alexander was planning to build.

The eastern boundary, defined as a meridian situated at 32°38'E, created some discomfort for the ancient geodesists because a certain portion of the Nile, including the all-important First Cataract, actually lies east of this boundary by about 15'. The Egyptians rectified this anomaly by arbitrarily extending the region of the First Cataract, and therefore its southern border, about 50 or so miles southward to the point where the meridian of 32°38'E bisects the Nile right at the latitude of 23°N. This artifice added an extra degree to the geodetic length of Egypt (making 8 degrees total), and, in so doing, rationalized and justified the establishment of Thebes (Waset) as the new geodetic and cultic capital of Egypt. This switch may well have occurred as early as the onset of the Middle Kingdom around 2,200 B.C. and was to have serious geopolitical repercussions in Africa because it may have precipitated the centuries-long conflict between Egypt and Cush. In attaching this stretch of Lower Nubia in this fashion, it is evident that the Egyptian dynasts were clashing head-on with the interests of Cush who had exerted a hegemony in that region for a long time, if in fact it wasn't already a part of their country. In some ways, the reverberations of that rather imperious long-ago geopolitical act are still being felt today in those regions.

Stecchini insists that, because of its advanced geodesy and mensuration, it became convenient to consider Egypt's prime meridian of 31°14'E as the prime meridian for the whole world. He claims that Mesopotamian, Mediterranean, and Asian capitals were established in whole number or simple fractional relations to the Egyptian zero meridian. Thus, Egypt's prime meridian functioned exactly as the contemporary prime meridian, running through Greenwich, England, does. Moreover, Piazzi Smyth insists that the building of the Great Pyramid and the establishment of the zero meridian through its apex was also dictated by the fact that that meridian runs through more of the earth's north-south land surface than any other meridian. Complementarily, the pyramid's parallel of latitude runs through more of the earth's east-west land surface than any other latitude (see Fig. 30). Thus, the Great Pyramid can be said to be the center of the earth's land surface.[48] It is no wonder ancient nations formulated their own geodesy in relation to the Great Pyramid. It is no wonder that, in 1884, a strong case was made to reestablish the modern prime meridian through the Great Pyramid until British and American pressure won the day for Greenwich, England.

[48] Piazzi Smyth, op. cit., p. 89.

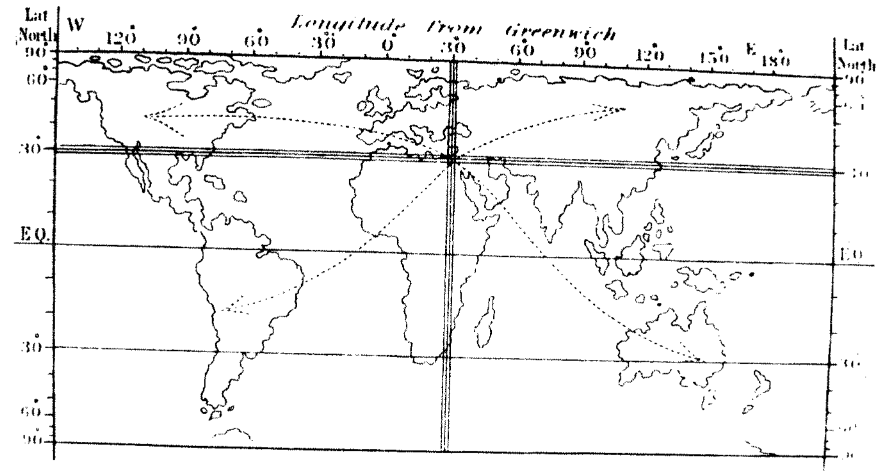


Fig. 30. The longitudinal line on which the Great Pyramid sits passes through more north-south land mass than any other global longitude; the latitudinal line of the Great Pyramid passes through more east-west land surface than any other. This makes the geodetic-geographic point of the Great Pyramid the center of the earth from the point of view of its surface land masses.

All this is very heady stuff. It means, among other things, that the ancient priests of Egypt—indeed, the priests of all civilized countries—knew as much as we about the size and shape of the earth. It suggests further that ancient civilizations all over the globe were linked in a web of commercial, scientific, and diplomatic relations not at all unlike that of the modern era. Few indeed are they who are prepared, by their previous psychological conditioning or academic training, to accept any part of it. There is a dawning suspicion, once one grasps the implications of the work done on the pyramid, that at a certain point in historical time, a kind of correcting fluid, a veritable "white-out," was (metaphorically speaking) applied wholesale to the book of history, following which a whole different version of history was overwritten upon the blanked-out pages.

Ancient Nilotic Measure and Geodesy

If the Egyptians were in possession of advanced geodesy, as encapsulated in the Great Pyramid, certainly they must have devised measures of degrees of latitude and longitude along with the speed of the earth's rotation. Indeed, the Egyptians had developed a system of measures that coordinated length,

volume, weight, and time.[49] Basic to this system was their unit of length, that is, the cubit. The cubit derives anciently from the length of pharaoh's arm between the elbow (*cubitum*) and the tip of the medial digit which was then formalized into a standard length. The smaller units of the cubit were subdivided into fingers, palms, and "fists." There were three forms of the cubit developed, beginning with the dynastic period and continuing to the Christian era. These were, in chronological order of appearance:

1. The "short" cubit of 24 fingers, 6 palms, 4 1/2 fists.
2. The Royal Cubit of 28 fingers, 7 palms, 5 1/4 fists.
3. The Sacred Cubit of 34 fingers, 8 1/2 palms, 6 3/8 fists.[50]

The short cubit measured 17.8 inches, the Royal Cubit 20.62 inches, and the Sacred Cubit 25.026 inches (see Fig. 31).

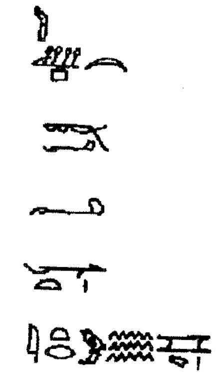
Other measures derived from the cubit were also in use. One such was the remen, composed of 20 fingers, 15 palms, 5 fists and spanning 14.83 inches.[51] Erik Iversen, author of *Canon and Proportion in Egyptian Art*, asserts that there was another Egyptian measure that he calls the "2/3 measure," consisting of 16 fingers, 4 palms, 3 fists and spanning 13.75 inches.[52]

Stecchini, in his appendix to Tompkins' book, has produced a lengthy discussion of the measurements of the degrees of arc of both latitude and longitude. The documentary evidence derives from an inscription discovered at Karnak Temple at Waset (Thebes). Ludwig Borchardt was the first in 1921 to discuss the geodetic implications of the inscription, though he ended by concluding that the possibility that the Egyptians measured their national dimensions by our equivalent of latitude must be absolutely excluded, apparently for no other reason than such advanced geodesy among them was considered intrinsically impossible. In brief, the inscription describes the exact distance between Behdet, located on the Mediterranean coast on Egypt's zero meridian, and Syene at the First Cataract:

> The inscription states that the distance between Behdet and Syene, the area of the First Cataract, is 106 *atur*, and divides this distance into 20 *atur* from Behdet to a place called Pi-Hapy, and 86 *atur* between Pi-Hapy and Syene.[53]

[49] Stecchini, op. cit., pp. 316–7.
[50] The existence of the "Sacred Cubit" is highly controversial since it is not specifically attested in the texts. Isaac Newton was the first to suggest its existence in the now-obscure pamphlet he wrote on the Great Pyramid. Others, such as Piazzi Smyth and Schwaller de Lubicz, accepted the historicity of the Sacred Cubit. Like other measures, it is said to be built into the dimensions of the Great Pyramid.
[51] See the problem of the "double remen" in Chapter 3.
[52] Mensurists such as Piazzi Smyth and Stecchini, among others, derive the modern inch, foot, and meter from these ancient measures.
[53] Stecchini, op. cit., p. 333.

MEASUREMENT OF LENGTH



Measurement	Transliteration	Translation	Equivalent
	dbʿ	digit	0.73 inch
	šsp	4 digits or palm-breath	2.98 inches
	mh	28 digits or 1 cubit	20.64 inches
	mh	7 palms or 1 cubit	20.64 inches
	ht	100 cubits or 1 rod	171.6 feet
	itrw	"river measure" 20,000 cubits	6.5 miles

Fig 31. Units and subunits of cubit measure showing both a septenary ("7s") and decimal character.

Apparently, it had crossed Borchardt's mind that these different distances reflected degrees of latitude but, as indicated above, he literally banished the thought. Stecchini exhibited no such qualms and determined the length of one atur to be 15,000 royal cubits. In using the inscription to support his figure, he points out that the difference in latitude between Behdet and the southern limit of the first Cataract is 7°30', and, on the basis of 15,000 cubits per one atur, the inscription distance of 106 atur equals 1,590,000 royal cubits. This distance of 1,590,000 royal cubits between Behdet and Syene equals 833,395.8 meters. The known geodetic difference of 7°30' between Behdet and Syene is equal to 831,091.6 meters so that the Egyptian distance, on the basis of 15,000 royal cubits per atur, exceeds the known geographic distance by less than 1 atur, 2/7 atur (2300 meters) to be exact.

Stecchini makes the point that, in predynastic times, a measure between the short cubit of 17.8 inches and the royal cubit of 20.62 inches was used. Though this intermediate measure, like the short cubit, gave way to the royal cubit, it was used in geographical measurements because it yielded more precise results. Stecchini calls this measure the "geographic cubit" and it continued to be used, first by the Greeks, and then by the Arabs through the 19th century. The geographic cubit measured 18.15 inches. The reason why the geographic cubit was more suited to geodesy is that it gave whole, round numbers for the minutes of latitude and longitude respectively. We know, for example, that the apothem (the median line of the triangular face from the base to the apex) of the pyramid measured 352 *royal* cubits but exactly 400 *geographic* cubits; the side of the base of the pyramid measured 440

royal cubits but exactly 500 geographic cubits. It is known that the Cnidian philosopher Agartharchides reported that the pyramidal apothem of 400 geographic cubits represented $^1/_{10}$th of a geodetic minute and the side of the base of 500 geographic cubits $^1/_8$th of a geodetic minute; 4,000 geographic cubits thus equals exactly one geodetic minute (at the latitude/longitude of the Great Pyramid). Knowing this allows anyone to calculate the degree of latitude/longitude at the locale of the Great Pyramid. Moreover, it shows why the geographic cubit was more suitable for geodetic measurement than the royal cubit. However, the royal cubit maintained pride of place because it could be related to the septenary system governing Egyptian science and technology. All this being said, the 106 atur between Behdet and Syene could just as well be ramified, in Stecchini's view, to 1,802,000 geographic cubits (17,000 geocubits to an atur), giving a distance of 831,971.7, an excess of only 880.1 meters over the true distance. Thus, using the geocubit measure in round numbers gives greater precision than the royal cubit.

Above, we saw how the Egyptians obtained a meridian by using the Grand Gallery as an observatory to measure the passage of a certain star across the viewing aperture. This, then, would have been the method for obtaining longitude. Stecchini and Tompkins also note that once the observational apparatus of the Grand Gallery was in place, it also allowed the Egyptians to correlate length and time. The rotation of the vault in heaven, with the motion of the stars transiting across the meridian, gives an "absolute" time reference and, it just so happens, as Tompkins determined, the speed of rotation of the vault could be measured at *1,000 geographic cubits per second*.[54] This, too, allows more accurate determination of the longitudinal axes.

It struck this writer as he was reviewing the evidence showing substantial ancient Nilotic knowledge of the movements of the heavenly bodies through time and space that there was something very "Keplerian" about it all. Kepler was the 17th-century astronomer credited with the discovery of the laws of planetary motion that were directly responsible for Newton's discovery of gravity. The entire edifice of modern physics rests upon the labors of these two men. Be that as it may, this intuition concerning the Keplerian knowledge of ancient Nilotic astronomers was initially dismissed because there was no evident support for it until the author came across the work of Richard Anthony Proctor, who wrote:

> We know that [among the Egyptians] some harmonious relation between the distances and periods was supposed to exist. When Kepler discovered the actual law, he conceived that he had in reality found out the mystery of Egyptian astronomy, or, as he expressed it, that he had 'stolen the golden vases of the Egyptians.'[55]

[54] Ibid., p. 317.
[55] Proctor, op. cit., p. 262.

To this we might add that the *only* way time can be defined is as "movement through space," which underlies the Einsteinian conception of the universe as "space-time." Since the astro-architectural evidence shows that the ancient Nilotes had measured the relationship of time and space in exactly this way, it seems that more recent physicists have also recovered the "golden vases" of the Egyptians in the elaboration of their science.

The reader is invited to consult Tompkins's book, particularly Stecchini's treatise at the end, for more extensive details on these subjects. Suffice to say, the Egyptians had generated for themselves all of the analytical tools, tables, and data necessary to measure their country, their continent, *and* the world. That they actually did so is the subject of Chapter 6.

Before leaving the subject of the Great Pyramid, it is worth noting some other unusual features concerning it. Petrie was one of the first to call attention to an almost imperceptible hollowing effect in the Great Pyramid. This is to say that its triangular faces slant slightly inward toward their respective apothems. Up close, this effect is virtually impossible to detect on direct observation though it becomes evident on aerial photographs.[56] We should say more accurately that the effect is impossible to detect *except* at the spring equinox. As Pochan aptly demonstrates (with published photographs), at 6:00 a.m. on the morning of the spring equinox, a combination of light and shadow caused by the rising sun passes rapidly across the pyramid's southern face from left to right. This "flash" is a direct consequence of the pyramidal hollowing. At 6 p.m., 12 hours later, the flash reverses itself going from right to left. Thus, as Pochan notes, were the ancient Egyptians able to determine the equinox within 12 hours.[57] This, by the way, helped them keep track of the Precession since they would be able to mark the movement of the background of stars relative to the equinox year-by-year, century-by-century, millenium-by-millenium.

Another "calendrical" feature has been noted at the spring equinox, because at noon on that day, the pyramid "swallows its shadow." This means that with the sun overhead at noon on that day, the pyramid does not throw a shadow. Given these two means of determining the exact timing of the equinox, the pyramid, among its other functions, served as a gigantic almanac.

Even this summary treatment of the properties and functions built into the pyramid conveys the impression that something more than ordinary human genius went into its construction. Piazzi Smyth and other early pyramid enthusiasts thought they were contemplating divine Biblical revelation of the same nature as God's talk with Moses. Erik Von Daniken won a worldwide audience for his suggestion that only "space invaders" could have been

[56] See Pochan, op. cit., photos after p. 136.
[57] Ibid., pp. 231-2.

advanced enough to have built it. Yet we have nothing that concretely shows that any extraordinary machinery or supernatural technique went into its building. The pyramid appears to have been built with the tools of the time with an almost unfathomable ingenuity. More will undoubtedly come light about the Great Pyramid though it is hard to know if all of its essential mysteries will ever be revealed.

Some Facets of Nonpyramidal Nilotic Architecture

It is pertinent now to examine further some of the building principles underlaying Nilotic nonpyramidal architecture. In our discussions of pyramid building, we have already seen that limestone was the primary building material of the Nile Valley throughout the dynastic period. Limestone is a soft rock and the other soft rock used extensively for building purposes was sandstone, not significantly exploited for construction until the 18th dynasty (c. 1,580 B.C.). Egyptian alabaster was the only other soft rock used by the ancient Nilotic builder but on a much smaller scale than either limestone or sandstone.[58] Building-quality limestone can be found in the Nile Valley from Cairo to Nubia; quality sandstone is scarce above the 1st cataract. Quarrying methods, show, as Clarke and Engelbach indicated, the same orderliness and efficiency that characterized all other aspects of Nilotic building methods. Stone was cut away in roughly rectangular blocks, leaving nearly vertical quarry faces, instead of being wrenched from the quarry site. The standard view of the type of tools used to extract the stone characterizes them as made of well-tempered, constantly resharpened bronze or copper. And yet,

> . . . the tool was driven into the stone almost vertically, that small trenches were cut across the line of the separating trench at intervals of from one to two inches, and that the stone between these trenches was chipped or hammered away. It must be admitted that to do this would require a tool of great hardness.[59]

Since we now have evidence that iron was known and used in the Nile Valley from Old Kingdom times, it is worth posing the question of whether steel was also. As we have said in Chapter 2, iron conveys little advantage over bronze unless it is hardened by carburization to make steel. As Clarke and Engelbach suggest in the above quote, the kind of quarrying practiced by these ancient builders required hardened tools. Was ancient Nilotic bronze up to the task or was it steel that was employed for this purpose?

In addition to the soft rocks of limestone, sandstone, and alabaster, ancient Egyptians used the hard rocks granite, basalt, diorite, and quartzite, prin-

[58] See Clarke and Engelbach, op. cit., pp. 12-33, for an extended discussion of the building stones used in the ancient Nile Valley.

[59] Ibid., p. 18.

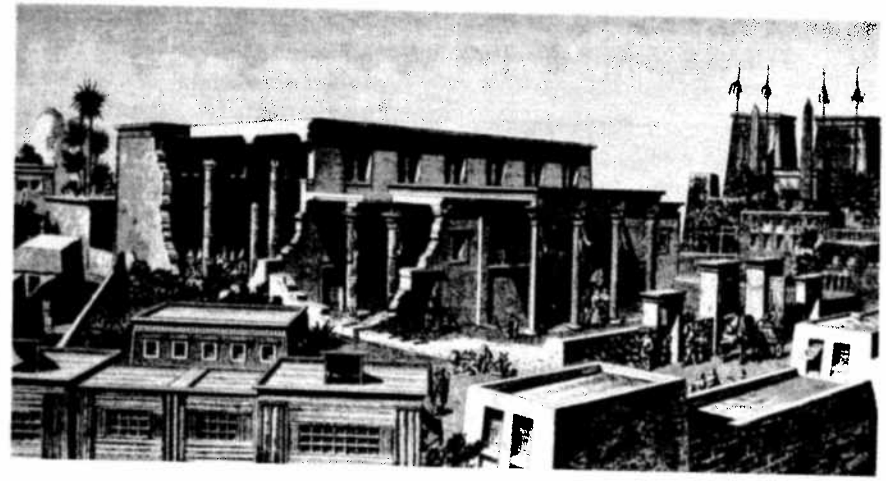


Fig. 32. Palatial home of a high Egyptian official.

cipally for statues, obelisks, and special interior structures of the temples. Basalt and quartzite outcroppings were found chiefly in the regions around Cairo; granite, almost always found as large boulders, was obtained almost exclusively from the east bank of the Nile at present-day Aswan. According to Clarke and Engelbach, the hard rocks, particularly granite, were extracted by wedging and pounding with dolerite balls. Again, the issue of the metal tools used has caused tremendous perplexity because all of the standard authorities have been constrained by conventional ideas about the beginnings of the Iron Age:

> Nowadays, the only metal used on the hard rocks is steel. To attempt to use copper, however much one may temper it by heating and hammering it, is to ask oneself whether the Egyptians did not use a tool of a hardness approaching tool-steel. It is tolerably certain that steel of this hardness was not known to the Egyptians.[60]

Thus, do the experts tie themselves into knots by their *a priori* reasoning. Be that as it may, it is known that these Nilotic technicians were able to quarry and *carry by ship* single blocks of granite weighing *two million pounds*.[61]

All the essential steps in the building process undertaken by modern architects are evident in the ancient Nile Valley. Pre-construction activities included drawing of plans and creating scale models, of which examples of both have survived. Indeed, such plans and blueprints were an indispensible

[60] Ibid., p. 25.

[61] Ibid., p. 34.

feature of temple archives since so many of them were rebuilt hundreds of years after initial construction along the same lines and in the same spot as originally. The architectural blueprint was always drawn on a squared papyrus surface, as were those of busts and statues. Virtually without exception, stone constructions and sculptures followed the well-known Canon of Proportion, most readily achieved by the technique of drawing on squared surfaces.

Clarke and Engelbach have criticized the ancient builders because, for most of dynastic history, the temples lack substantial foundations; some were built on no foundations at all.[62] It is only during the 25th or Ethiopian Dynasty that the builders of the Nile Valley began to establish solid foundations for their buildings:

> . . . under the princes of that country [Ethiopia] the buildings show a prodigality of materials in the foundations. Far from making a few trenches and holes to receive the walls and columns, the whole area of the temple was completely covered with carefully laid blocks three or four courses deep.[63]

Part of the reason why, prior to that time, seemingly lesser attention was paid to the foundation was because the walls and pillars of the temples tended to be so massive that strong foundations were somewhat superfluous.[64] It was the solidity and massiveness of the supporting structures that gave the buildings their stability. This same rationale applied to mortaring. Many commentators on ancient Nilotic building methods have remarked on the fineness of mortaring in Nile Valley buildings, allowing blocks to be apposed to within $^{1}/_{50}$th of an inch of one another. But unlike building in later civilizations, mortar did not serve as a cementing material but a lubricating one, that is, a lubricant that allowed the blocks to be moved easily into place. Again it was the massiveness and solidity of the walls and columns that stabilized the building rather than the cohesion of the mortar. Thus, it can be seen that in the Nile Valley megalithic building was accomplished without mortar in the contemporary sense of it.

We have already touched on some of the methods employed by Nilotic builders to move huge, megalithic blocks. Granite blocks weighing hundreds of tons were floated on barges more than 500 miles down the Nile from their quarrying sites in Aswan. Exactly how this was accomplished is still somewhat mysterious. Sleds were also used and could haul heavy blocks of many tons gliding over surfaces made slick by lubricant applied ahead of the moving sled. Though, as we have seen, wheels were not used in the building projects of the Old and Middle Kingdoms, logs functioning as rollers were. Rockers, often in conjunction with levering implements, also served to appose the blocks tightly against one another.[65]

[62] Ibid., pp. 69–77.
[63] Ibid., p. 76.
[64] Clarke and Engelbach do point out that most of the important medieval buildings, many still standing, were erected without foundations. Again, for them it is a point of criticism whereas it may be that for buildings constructed in a certain way, foundations are not the most essential feature. Ibid., p. 77.

Though the Nile Valley civilizations were justly famed for their stone architecture, they were as skilled in the uses of brick. Indeed, most buildings, including the homes of the citizens of all classes, were built of brick. Even pharaonic palaces were of brick instead of stone, the latter material being reserved almost exclusively for sacred buildings. Bricks were made of Nile mud and, in the hot, dry climate, allowed to dry in the sun. Other cohesives added to the bricks consisted most commonly of wheat chaff or sand.

These bricks were fashioned by the millions and went into the construction of, among other things, walls attaining a height of 45 feet and a thickness of up to 80 feet. Few brick structures from dynastic times still stand, though, in this century, outstanding examples of brick masonry could still be seen at the ruins of the fortresses at Semna, Kumma, and Buhen in Nubia. Clarke and Engelbach noted also that grids of wooden beams were sometimes laid in every fifth concourse of a brick structure to stabilize it and prevent cracking.[66] This use of wooden beams is of more than casual interest because, as will be seen later in this chapter, the same technique was adopted in the mud-brick architecture of the Western Sudan, whose resemblance to Nilotic architectural forms has struck a number of observers.

The better homes and the palaces of the rich often attained great size, with more than a few able to accomodate 60 people. The royal palaces in particular were notable for their splendor, built with courtyards, gardens, and lakes. Indeed, every Egyptian of means maintained a garden where most of the leisure hours were whiled away. Walls and windows were constructed in such a way as to catch the northern breezes to keep the house well-ventilated. In the cooler months, particularly in the Delta, the thick brick walls also insulated the household within. Most of the better homes possessed indoor toilet facilities and, occasionally, running water. Mostly, water was brought in from wells or from the Nile (see Plate 16); waste water was carried out of the house and allowed to soak into the surrounding sand. However, in several cities, most especially Akhetaten and Buhen in Nubia, a well-planned and constructed public drainage system served the entire populace.[67]

[65] Ibid., pp. 88–93.
[66] Ibid., p. 210.
[67] See Badawy A, *Architecture in Ancient Egypt and the Near East*, Cambridge: M.I.T. Press, 1966, pp. 21–33.

The Astro-architecture of the Ancient Nile Valley

The astronomical relations governing the architecture of the Great Pyramid had begun to be recognized by the middle of the 19th century. However, it was not until the last decade of that century that the astronomical determinants of other Egyptian temples were established. This was almost entirely due to the work of Norman Lockyer who, like Piazzi Smyth, was an eminent astronomer in his own right. He had done some of the seminal work on sunspots and was the first to identify helium as one of the primary elements in the sun. Moreover, he was the founder and first editor of *Nature*, still one of the most influential scientific journals in the world. In spite of such gilt-edged credentials, his work on the astronomical orientations of Egyptian temples, set forth in the *Dawn of Astronomy* in 1894,[68] did nothing to endear him to either his colleagues or Egyptologists. Though not an evangelical Christian or Bibliolater like Piazzi Smyth, Lockyer did use the results of his investigations to launch into some highly speculative explanations concerning the dates of origin of Egyptian civilization. Nonetheless, his empirical work was and remains rock-solid. Furthermore, he applied his methods to an analysis of the astronomical orientations of Stonehenge, again to the derision of archaeologists. They stopped laughing, however, when Gerald S. Hawkins proved Lockyer right in 1963.

We will deal more fully with Lockyer's reconstruction of Egyptian astronomy in the next chapter, but we can introduce his work here since he was able to show the interconnection between Egyptian architecture and astronomy. Lockyer based his early work on the orientation of Egyptian temples on the temple surveys performed by the French under Napoleon in 1799 and the Prussians under Lepsius in 1844. That did not prevent him from travelling to Egypt on his own in 1890 to take his own measurements and sightings, particularly since neither the French nor the Prussians seemed to have drawn any conclusions relative to the astronomical implications of the alignments and orientations they had determined. But Lockyer found that temple after temple showed an axis of orientation precisely aligned to certain important stars. More astonishing from Lockyer's standpoint, temple axes seemed to have been deliberately altered by extended construction in order to "follow" a star as it, over a period of centuries, shifted away from the original alignment. In some cases, whole temples were completely abandoned and others erected in order to re-establish the correct alignment with a certain star. These axial shifts, among other things, convinced Lockyer—as others had been convinced from other data—that the Egyptians possessed a perfect knowledge of the Precession, of both the equinoxes and the polestars.

The Temple of Amon at Karnak, the largest of its kind in the world, was

[68] Lockyer JN, *The Dawn of Astronomy*, Cambridge: The M.I.T. Press, 1964.

constructed and oriented in such a way as to represent a perfect illustration of Lockyer's findings. The axis of the temple pointed toward the western hills across the Nile at a declination of 24°18'.[69] Lockyer points out that the obliquity, i.e., the tilt of the earth's axis, though 23°27' today, was, in 5,000 B.C., 24°22', meaning that the tilt has "straightened" by nearly 1° in 7,000 years. From these data, Lockyer concludes that the axis of the temple was originally aligned with the setting sun at the time of the summer solstice as early as 3,700 B.C. At that date, the sun at noon would have been poised directly overhead at the Tropic of Cancer at 24°18'N, corresponding to the declination of the axis of Karnak Temple.

As to the temple structure itself, Lockyer observed that the axial corridor, from the entrance pylons, stretched in a straight line back through a series of halls and portals of gradually diminishing widths, coming to an end at the Sanctuary. The entrance pylons were unroofed but the interior halls, i.e., the hypostyle hall, would have been covered. This led Lockyer to say:

> From one end of the temple to the other we find the axis marked out by narrow apertures in the various pylons, and many walls with doors crossing the axis. . . . In the temple of Amon-Ra there are 17 or 18 of these apertures, limiting the light which falls into the Holy of Holies or the Sanctuary.[70]

Lockyer further states:

> . . . every part of the temple was built . . . to limit the light which fell on its front into a narrow beam, and to carry it to the other extremity of the temple—into the sanctuary, so that once a year when the sun set at the solstice the light passed without interruption along the whole length of the temple, finally illuminating the Sanctuary.[71]

What is more, it occurred to Lockyer that these architectural arrangements, concentrating and focusing the light of the setting solstitial sun in a surrounding darkfield created by the temple's interior, produced exactly the same effect as a telescope. That is to say, the apertures created by the series of gradually narrowing portals, pylons, and separating walls functioned exactly the way diaphragms do in a telescope.[72] No one has yet found a telescope among the artifacts of ancient Egypt but it is evident that they possessed more than a passing understanding of optics. Whatever the case, at the precise moment of its setting at the solstice, the sun would send a thin shaft of light down

[69] Ibid., p. 119. The reader should consult Lockyer's book to understand the technical details of his method.

[70] Ibid., pp. 103–4.

[71] Ibid. pp. 105–6.

[72] Ibid., p. 108. Lockyer might have also said that these diaphragmatic principles are also intrinsic to the modern camera.

the axial corridor, brilliantly lighting the interior sanctuary wall for a period of two to five minutes, enabling the priests to measure the exact duration of the solar year.

Lockyer has found similar arrangements in most of the important cult temples of Upper Egypt, whether oriented to the sun or to other stars in their risings or settings. The star temples, therefore, were designed to direct starlight into the sanctuary in the same manner as the axial corridor of Karnak directed sunlight into its sanctuary. The orientations were exact, carried out by the familiar "stretching of the cord," usually performed by pharaoh himself. Several inscriptions describe the method by which pharaoh performed the stretching of the cord ceremony while sighting a specific star.[73]

It is also pertinent to mention the manner in which the Egyptians managed to paint scenes with brilliant colors and exact drawings in the deepest, darkest recesses of their tombs and temples without benefit of burning torches. No traces of soot or any combustion has *ever* been detected in the temples traceable to the time when the temples were built. Since no one seriously imagines that the Egyptians possessed electric lighting, it has been determined that they used a system of mirrors to direct sunlight from the surface through the twists and turns of the temple corridors. No matter how far removed from open air the inner rooms were situated, the sunlight conveyed into them by the mirrors caused them to be illuminated as brightly as electric light.

We will continue the discussion of Egyptian "astro-architecture" in the next chapter.

Harmony and Proportion in Ancient Egyptian Architecture

> Nowhere . . . is the belief in the existence of an aesthetics of numbers, an eurhythmy based on the harmonious coordination of proportions and ratios expressed in naked numerical terms such as manifest in any Egyptian work of art, professed with greater force and lucidity than in Philo Byzantius' laconic quotation . . . "beauty emerges imperceptibly from a profusion of numbers."[74]

This axiom applies equally well to Egyptian architecture. As we have seen, most of what we know concerning the interconnections among number, geometry, music, and astronomy in ancient Egypt comes to us indirectly through the traditions passed on by the Pythagoreans and the dialogues of Plato. The governing principle of *all* these disciplines from the Egyptian standpoint was harmony. Indeed, one might say that harmony and all its correlatives—proportion, symmetry, and eurhythymy[75]—comprised the true definition of *Maat*. Harmony, of necessity, governed the creation of art and architecture as well.

There is a theme that recurs through several of Plato's dialogues, particularly *Timaeus*, *Laws*, and the *Republic*, that refers to the building of the ideal society. As John Michell points out, in Platonic society, only certain kinds of music are permitted, i.e., those emanating from the immutable laws of harmony which, in the playing, promote psychic stability and balance in the citizens of that society.[76] In *Laws*, one of the protagonists, an Athenian, laments the tendency of the nations of that time to allow musicians to compose and play any kind of music that whim and fashion dictated, without regard to their effects and consequences.[77] What interests us is that the Athenian commentator specifically relates that Egypt represents the sole exception to this state of affairs, that is to say, deharmonizing, "destructive" musical forms were expressly forbidden in that country:

> One could doubtless find things to criticize in other Egyptian institutions but in the matter of music it is a very noteworthy fact that it has proved possible to canonize those forms of music which are naturally correct and establish them by law.[78]

As Michell tells us:

> By Plato's time the very idea of a canon of music had been forgotten everywhere except in the academies of Egypt, but he himself had evidently studied and learned it, for the number code behind it is at the root of all his mathematical allegories.[79]

The evidence is clear: it is in Egypt that the concept of music providing a harmonic guide to govern society was elaborated. Furthermore, that harmony was definable by number is also an Egyptian concept. Since society, in the form of a sacred city, had to be established according to the rules of harmony and numerical proportion, it followed that art and architecture in the ideal society had to conform to harmony and numerical proportion as well.

Plato espoused some definitive if lofty ideas on how to construct the earthly version of the cosmic city. As Michell, Schwaller de Lubicz, and others reveal, the Temple was the central institution around which this pre-Christian "City of God" had to be constructed. Thus, Michell tells us:

> Like all products of the canon, the temple was also a world-image, synthesizing in its proportions the measurements of the human frame with those of the cos-

73 Ibid., pp. 173–9.
74 Iversen, op. cit., p. 13.
75 Iversen defines *proportion* as "the correct adjustment of the parts to anthropomorphic standardization;" *symmetry* as "the commensurability of the parts;" *eurhythymy* as "the coordination of proportion and symmetry into a harmonious unity in accordance with the established aesthetics of numbers"; ibid.

76 Michell J, *The Dimensions of Paradise*, London: Thames and Hudson, 1988, pp. 12–3.
77 It will not escape the attentive reader that this passage has implications that spill over into the modern day where a kind of "anti-music" has evolved that both mirrors and impels the social deconstruction everywhere evident.
78 Cited in Michell, op. cit., p. 13.
79 Ibid.

> mos. It was designed on the principle that "like attracts like," on the understanding . . . that if one wishes to attract any aspect of the universal spirit one must create a receptacle in its image.[80]

In earlier parts of this book, we have alluded to the numerical proportions and constants such as π and φ built into the Great Pyramid. Other numerical constants and values dictated the architectural design of pyramids and temples alike. One such was the $^4/_3$ proportion noted by Bent Hansen in the Step Pyramid, the Great Pyramid, and other temples in Egypt.[81] Now the $^4/_3$ proportion takes us once again back to the "Pythagorean" harmonic scale. Proceeding up the scale from C, the tones are created by the 8:9 proportion (of string length) until E (and later B) is reached. The tone ratio composing E, of string length $^{64}/_{81}$, is created by the operation $^9/_8 \times {}^9/_8$ which = 81/64.[82] However, to go from E to F can only be accomplished by producing a semitone, obtained by multiplying $^4/_3 \times {}^8/_9 \times {}^8/_9$, that is to say multiplying $^4/_3$ by E's string length of $^{64}/_{81}$, giving the leimma of $^{256}/_{243}$ (see Chapter 3).

It would therefore seem that a key constant of the harmonic scale was built into the pyramids and temples of ancient Egypt. We have already mentioned that the leimma of $^{256}/_{243}$ is exactly one-third of the Rhind value for π of $^{256}/_{243}$. And, in fact, if the E ratio of $^{81}/_{64}$—from where the leimma is generated—is multiplied by the Rhind π of $^{256}/_{243}$, one obtains the double-octave, defined by a string length of 1/4 and a tone ratio of 4. Since the double-octave was considered the limit of the ordinary human voice, Pythagorean harmonics ended there. The reader will notice, however, that at the end of all of this stands the all-powerful number 4 which anchors so much of African number symbolism.

One notices that this all-important $^4/_3$ constant that we continue to encounter in any discussion concerning Nilotic harmonics, geometry, and architecture is exactly the *double* of $^2/_3$. We have already seen how important the $^2/_3$ fraction is in the ancient Egypt arithmetic system and we are entitled to surmise that it is derivable from this harmonic constant of $^4/_3$. Since the ancient Nilotes kept everything perfectly consistent, we see the doubling and halving that dictated their mathematic operations is perfectly preserved here with $^4/_3$ being *double* $^2/_3$ and $^2/_3$ being *half* of $^4/_3$.

Gradually we see everything in the Egyptian cosmos—earthly and heavenly, human and divine, material and spiritual—integrated into a whole, and

[80] Ibid., p. 16.
[81] See Hansen BH, "An Architectural Analysis of the Great Pyramid," in *Proceedings of the First International Symposium on the Application of Modern Technology to Archaeological Explorations at the Giza Necropolis*, Cairo: Egyptian Antiquities Organization, December 14-17, 1987, pp. 206–219.
[82] The tone ratio is *always* a reciprocal of the string length (of the monocord). Thus, a string length of 1/2 gives a tone ratio of 2, and so on.

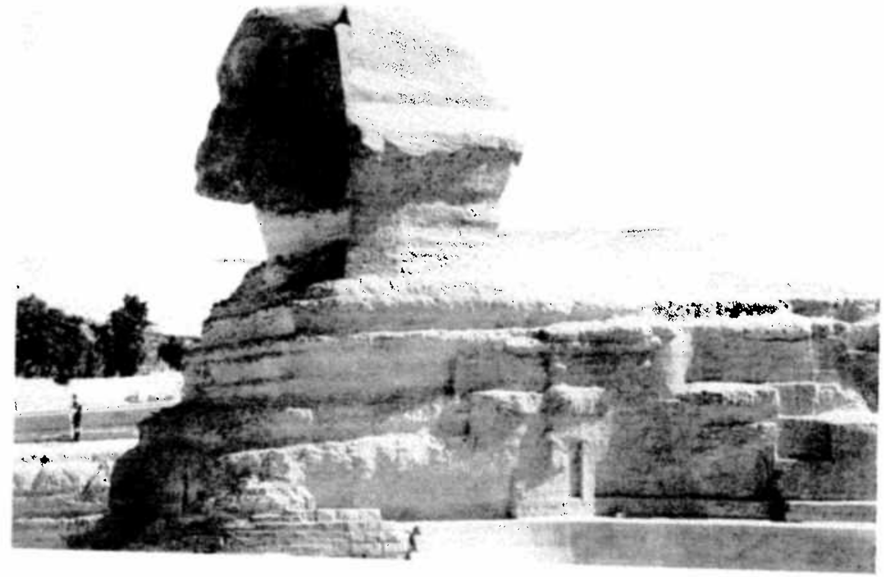


Plate 1. A profile of the Sphinx in its quarry showing the erosive patterns on the Sphinx's body and the surrounding quarry wall caused by rainfall. (Photo: V.D. Floyd)

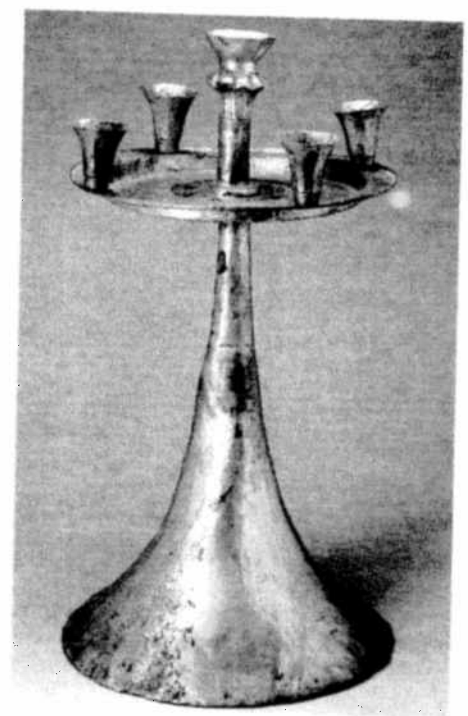


Plate 2. Bronze offering stand from Napatan Cush, circa 750 B.C., at the outset of the 25th Dynasty. (Photo: Museum of Fine Arts)