

Pyramids to Pythagoras: Surveying from Egypt to Greece – 3000 B.C. to 100 A.D.

John F. BROCK, Australia

SUMMARY

There is no doubt that the first renowned Grecian mathematicians, Thales and Pythagoras, went to Egypt as well as Babylon in a quest to learn from the reputed practical exponents of mathematical applications through which these long established ancient civilizations had founded their calculating prowess.

However, it was also recorded by the first historians, Herodotus (c. 450 B.C.) and Strabo (c. 24 B.C.) that the Greeks adapted many of the Egyptian calculation and surveying techniques, modifying and developing them with their own sophisticated advancements into a very refined system. The Greek surveying was in turn inherited and further progressed to an even greater level of accomplishment by the Romans, whose procedures were well recorded in such publications as the *Corpus Agrimensorum*, and whose equipment and individuals were well recovered from the legendary site of Pompeii frozen in time in the year 79 A.D. on the 27th August.

Not much is known of the Greek surveyors but in the following paper you will be taken on a mystical journey of discovery through ancient Egypt and Greece to marvel at the superb levels of surveying computation and field skill present. You will also witness the high ethical foundations laid down by our ancient forefathers as we travel back in time to 5000 years ago to the early years of ancient Egypt and then forward 3000 years to just after Pompeii was buried.

In the first part of the paper will be revealed the extraordinary level of refinement to which the Egyptian Survey Department had already risen even in the very earliest formative period, together with a brief familiarization of standards of measurement, surveying equipment, training methods for the Scribe surveyors, their field recording material and calculation techniques. The transferal of geometric knowledge from the Egyptians to the Greeks is shown to commence with Thales and Pythagoras travelling to Egypt and transporting their learning back to impart to their pupils in Greece. Two ancient Greek surveyors of particular note are revealed and the orthogonal town plan is shown to be transmitted from Egypt to Greece and then onto the Romans.

As we travel forward from these older eras of antiquity we move through the Heroic Age of Greek mathematics, see Alexander the Great found Alexandria as the greatest centre of learning in the ancient world where legendary figures such as Aristotle, Plato, Archimedes, Eratosthenes, Hero and Claudius Ptolemy make the city a fabled haven of science, mapping and surveying. To cap off a wondrous journey of revelations I leave it to two of the more renowned Greek historians, Herodotus and Strabo to leave us in no doubt that the Greeks of

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John F. Brock

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antiquity owed their great debt to the “rope-stretchers” of Egypt, or Scribe surveyors as they should more correctly be called, for passing on their brilliant ability in geometry (literally: “earth measure”) to them and ultimately to the Romans

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1. INTRODUCTION

*“3 cubits, 4 hands, 3 fingers; (1.92 metres)
3 cubits, 5 hands, 2 fingers; (1.96 metres)
2 cubits, 2 fingers; (1.2 metres)
3 cubits.” (1.57 metres)*

From the Palermo Stone (c. 2350 B.C.)

So can be read a five year record (the fifth year line was broken away) of the exact flood heights of the Nile River from a fragment of the Old Kingdom basalt stele known as the Palermo Stone dated to about 2350 B.C., near the end of the Egyptian Fifth Dynasty. The stone not only bears this accurate flood data, along with a full King List from the first Pharaoh, Menes, there are other historical details of the previous 500 years including a reference to a “numbering of gold and lands.” According to Sir Henry Lyons in his 1927 article in the Royal Geographical Society Journal this “numbering” of the Royal possessions, made every two years throughout the land by the officials of the Treasury, would have been a sort of verificatory survey of the State property which doubtless included herds as well as land, and this biennial census was so regular a procedure of the administration in these early times that events in the reign of the King were dated with reference to it.

Hence what is demonstrated on this stone is a firmly established and well administered Treasury, Land Registration and Survey Departments which played a major hand in the phenomenal capital works program of the Old Kingdom (2700-2200 B.C.) during which the Great Pyramids of Giza were so accurately set out and meticulously constructed.

From a 2700 B.C. wooden statue of the temple official, Mitry, known as the Councillor and Overseer of Boundaries, it can be seen that even as early as the very beginnings of the Golden Period of the great civilization itself, there was a very strong and active administration of surveying annexed to the King’s government.

2. EGYPTIAN SURVEY DEPARTMENT

“Remove not the boundary stones of the cornland and change not the position of the measuring tape.”

Amenhotpe, son of Kanakht,
Teachings, Chapter VI (c. 1400 B.C.)

Such was the revered authority of the surveyors and the boundary marks placed by them in the governing religious hierarchy of ancient Egypt at the time of Thutmose IV (or Thutmosis as the Greeks were to call him). Texts even refer to setting boundary stelae “like the sky”, such monumentation bearing the name of the King and the owner together with the extent of the holding being formally sealed and registered at the Survey Department. One such stela, given by Thutmose IV to a priest of Amun, is now in the Cairo Museum. Upon it the vizier Rekhmere tells of his daily duties as it is “he it is who divides all the land into fields. When a petitioner comes and says ‘Our boundary stelae have been removed’, he must see what is recorded under the seal of the responsible official, and so cause to be given back what has been taken away by the committee which has had the stelae removed.” (18th Dynasty – c. 1400-1350 B.C.)

3. STANDARDS OF MEASUREMENT, EQUIPMENT AND TRAINING

Surviving measuring rods found at work sites and in graves as funerary offerings testify to two main units of length in the ancient society: the small cubit of about 45 centimetres in length divided into 6 palms, each of which was further separated into 4 fingers, with even fractional divisions from halves down to sixteenths contained on some rods. For building and land surveying the larger Royal cubit, *mh*, (about 52.5 centimetres) was adopted, such unit having hieroglyphic representation being the forearm from the elbow to the fingertips.

The Egyptian area unit of 100 square cubits was called the *kht* (2735 square metres), but was later to be renamed the “aroura” by the Greek occupiers. There was also an interesting river distance called *itrw* estimated to be about 20,000 cubits (10.5 kilometres) to be subsequently named the “schoenus” by the Grecians.

To measure lengths and make set outs the Egyptians used treated ropes 100 cubits long called the “rod of cord” (*nwh*) divided by knots, as shown in the scene from Menna’s tomb (c. 1400-1350 B.C.). The “rod of cord” was considered divine and thus was stored in a cache bearing the sacred ram’s head of Amun as shown on the arm of Amenhotpe-si-se’s assistant and the scribe Penunhuret’s basalt statue.

For leveling a triangular plumbbob level was utilized called *sb₃* with its hieroglyphic determinative an image of the device itself as shown in the diagram. For the propagation of straight lines of sight the split palm leaf and plumb line, called the merchet, were employed,

along with the staff or gnomon often seen held by the King or Scribe of the Fields in wall paintings. There is even an image of Amenhotep II holding a staff with a forty five degree bend at the top and graduations along the shaft.

Only the children of the upper class were chosen to be offered the divine privilege of scribe training, which was a rigorous regime from the age of twelve (12) years for some dozen or more years to learn over 700 hieroglyphic signs and other practical skills in many areas. Strict discipline from dawn to dusk was based on the motto: “a boy’s ears are on his back.”

A Scribe of the Fields was multiskilled in surveying, calculation, agronomy, engineering and other associated areas, as testified on the biographical depictions of their lives on the walls of their tombs, such as Djoserkereseneb (c. 1400-1390 B.C.).

Surveyor scribes made their field notes on papyrus (sw) with reed or wooden pens stored in their palettes (*mnhd*) which had red and black ink pots on them. A writing board (^C*ny*) acted as a support for the papyrus and the style of writing would have been hieratic, the everyday script.

Mathematics in ancient Egypt was generated by a pressing need for practical decipherment of many of the problems associated with the determination of quantities and the relocation or redistribution of land boundaries after the regular Nile floodings. Very fine examples on papyri have survived from antiquity which provide us with first hand data of how these practical applications of computation were carried out on the Moscow, Berlin, Kahun and Rhind papyri. The last mentioned papyrus was written by a tutor Scribe called Ahmes and can be dated to about 1650 B.C. in the Fifteenth Dynasty during the Hyksos Period, but it was said to be a copy of a Twelfth Dynasty work (between 1985 and 1795 B.C.). Problems such as volumes of truncated pyramids, areas of fields and long multiplication and division were depicted on these various artifacts.

It is interesting to describe the Egyptian method for long multiplication, performed with a rudimentary recognition of binary numbers in the fashion I shall now highlight. To multiply 52 by 89 a table would be produced with the left column showing the number 1 followed by each number doubling the one before while on the right hand side the corresponding numbers would be derived by starting with 82 then doubling the succeeding numbers by the previous one:

1	89
2	178
* 4	356 *
8	712
* 16	1424 *
* 32	2848 *

Now since 32 is more than half of 52 no more numbers need to be tabulated, and 52 is made up of $32 + 16 + 4$ so the final answer can be obtained by adding together those numbers in the right column which correspond to the ones noted on the left i.e. 4,628.

Good accuracy was achieved by the ancient professionals as proven when modern measurements were made on the Great Pyramids by J.H. Cole in 1925 and Montagu in 1909 who checked comparisons of stated distances up to 15 kilometres with good agreement.

4. THE WORLD'S FIRST TWO MATHEMATICIANS TRAVEL TO EGYPT

Thales of Miletus (now in Turkey), 624-527 B.C., and Pythagoras (569-475 B.C.) from Samos, Ionia (now Greece) both travelled to Babylon and Egypt to seek learning from the widely reputed African civilizations. Both individuals have been draped in mystery with respect to the true nature of their achievements but both have been credited, by later historians in third hand accounts, with various theorems attributable to them.

According to Proclus, the last major Greek philosopher living around 450 A.D.:-

"[Thales] first went to Egypt and thence introduced this study [geometry] into Greece. He discovered many propositions himself and instructed his successors in the principles underlying many others, his method of attacking problems has greater generality in some cases and was more in the nature of simple inspection and observation in other cases."

Thales is generally accorded the derivation of five theorems:-

- 1/ A circle is bisected by any diameter.
- 2/ The base angles of an isosceles triangle are equal.
- 3/ The angles between two intersecting straight lines are equal.
- 4/ Two triangles are congruent if they have two angles and one side equal.
- 5/ An angle in a semi-circle is a right angle.

According to Boyer in *A History of Mathematics* Thales was "the first man in history to whom specific mathematical discoveries have been attributed."

While in Egypt it has been widely reported that Thales was successful in measuring the heights of the pyramids using similar triangles. Hieronymus, a pupil of Aristotle, as cited by Diogenes Laertius in the second century A.D., said: "that Thales" even succeeded in measuring the pyramids by observation of the length of their shadow at the moment when our shadows are equal to our own height", while Pliny said he did this "by measuring the shadow of the object at the time when a body and its shadow are equal in length", with Plutarch finally recounting that Thales "without trouble or the assistance of any instrument merely set up a stick at the extremity of the shadow cast by the pyramid and having thus made two triangles by the impact of the sun's rays ... showed that the pyramid has to the stick the same ratio which the shadow [of the pyramid] has to the shadow [of the stick]." Not only was he

well renowned for this what appeared to the Egyptians to be an incredible feat he also called upon the corpus of solar knowledge he had built up after absorbing so much from the Babylonians to predict a solar eclipse in 585 B.C., and despite his accurate premonition of this event some still choose it to be luck in preference to a genuine capacity for its forecast.

Pythagoras of Samos has been ascribed as the first pure mathematician. Most influential during his early life were Thales and his pupil Anaximander, also from Miletus, with whom he visited for two (2) years as an eighteen (18) year old in about 551 B.C.

Shortly after the tyrant Polycrates seized Samos, Pythagoras went to Egypt in 535 B.C., with some suggestions that he took with him a letter of introduction from the dictator to his ally in Egypt. Not only did Pythagoras absorb much mathematical knowledge from the Egyptians he also embraced much of the spiritual and religious doctrines which prevailed, returning to Samos to form a secretive cult of vegetarians known as the “semi-circle” of Pythagoras, eventually extinguished for their political covertness. Leaving Samos around 518 B.C. he settled in Croton (now Crotona on the eastern side of the heel in southern Italy) and founded a cultic school based upon religion, philosophy, mathematics and science. Such a broader sense of his school of learning is not surprising when one considers that Pythagoras was a contemporary of Buddha, Confucius and Lao-Tze !

Theorems listed as emanating from Pythagoras are in summary:-

- 1/ The sum of the angles in a triangle equals two right angles.
- 2/ The theorem of Pythagoras (even though its principles were known to the Babylonians in surviving texts !) – in a right angled triangle the square of the hypotenuse is equal to the sum of the squares of the other two sides.
- 3/ Constructing figures of a given area and geometrical algebra such as $a(a - x) = x^2$.
- 4/ The discovery of irrational numbers.
- 5/ The five regular solids
- 6/ In astronomy Pythagoras believed that the Earth was a sphere at the centre of the Universe, the orbit of the Moon was inclined to the equator, and was the first to realize that Venus as the morning star was the same planet as the evening star.

5. TWO ANCIENT GREEK SURVEYORS OF NOTE

Although little is really known of the ancient Greek surveyors and the work they did to realize the magnificence of the many amazing projects of the great civilization, there are two notable men who have immortalized their feats for posterity.

Not surprisingly one of these great ancient surveyor/engineers performed the first underground aqueduct construction on the island of Samos during the lifetime of Pythagoras. Eupalinos of Megara was engaged by Polycrates to construct the aqueduct under Mount Kastro in 550 B.C. Taking ten years to complete the tunnel is 1036 metres long, is 55 metres above sea level, 180 metres from the top of the mountain, and has dimensions of 1.8 by 1.8

metres. Starting from each side of the mountain the “two-mouthed tunnel” eventually met in the middle in a feat described by Herodotus, the ancient historian, as “one of the most significant technical achievements of Greek antiquity.” It is recorded that many Lesbian prisoners were employed by the Samians to complete the monumental task.

Hippodamus has been credited with the invention of the art of planning cities, having first laid out his native city of Miletus, famous for early science and widespread colonization, in 479 B.C. in a pattern of small and large squares. Commissioned to re-plan the Piraeus on a grid layout after the Persian Wars, he also took part in the establishment of Athens’ only colony in southern Italy, Thurii, in 443 B.C. with a resultant orthogonal street design. He is cited by O.A.W. Dilke in his book, *Greek and Roman Maps*, to have been the inspiration to the Greeks for such cardinal positioning of their lots and streets in towns and rural areas, as is evidenced in the substantial remains of the urban rectangles in the central district of modern Naples.

6. THE GRID TOWN PLAN OF EGYPT GOES FROM GREECE TO ROME

Although no examples of maps or plans for the design or layout of towns have survived from the Egyptians or the Greeks it is clear from the evidence of archaeological town remains in many different locations that the orthogonal type-site was adopted by both of these cultures when devising and setting out their cities and villages.

From Egypt some fine examples of orthogonal town planning can be seen from the Middle Kingdom town of Kahun, the New Kingdom workmen’s village of Deir el Medina in western Thebes, and also the Eighteenth Dynasty residential area of Amarna, from the reign of Akhenaten.

Such orthogonal planning from the Greek world has come to light through many modern investigations. Large urban grids were discovered in Asia Minor at Priene, Olynthus in the Chalcidice, and at Megalopolis in Arcadia, founded in 373 B.C. as a centre for greater urbanization and better defence. Some subsurface monitoring by the Canadian Archaeological Institute in Athens has found that the City of Stymphalos in northern Arcadia (now south Korinthia) had rectangular allotments of 30 by 103 metres with 6 metre wide streets. Aerial photography of more Greek colonies in southern Italy, Sicily and the Black Sea yielded similar data, while two systems of land subdivision were present in the adjacent Greek territories of Metapontum (now Metaponto) and Heracles (Policoro) from the south of Italy, with 6 and 7 kilometre long belts containing long strips of 230-240 metres wide oriented in cardinal directions from the streets.

Much information and physical examples of the adoption of grid style town plans by the Romans and Etruscans leave no doubt that such a heritage was passed on through the Greeks from the Egyptians.

7. THE HEROIC AGE OF MATHEMATICS UP TO 400 B.C.

Following Thales and Pythagoras came some remarkable individuals in the annals of mathematical breakthroughs up to around the year 400 B.C. Anaxagoras of Clazomenae (c. 428 B.C.), Hippasus of Metapontum (c. 400 B.C.), Hippias of Elis and Zeno of Elea (c. 450 B.C.), Hippocrates of Chios (c. 430 B.C.), Philolaus and Archytas (born c. 428 B.C.) of Tarentum, and Democritus of Abdera (460-370 B.C.).

Democritus is quoted as having said: “I would rather discover one cause than gain the kingdom of Persia”, which at the time was about the entire known world, and even though none of his texts have survived the titles of his books provide a clear view of his works: “*On Numbers; On Geometry; On Tangencies; On Mappings; On Irrationals, On the Pythagoreans; On World Order; and On Ethics.*” Having been purported to have travelled widely to Athens, Egypt, Mesopotamia, and even perhaps India, his admiration for the ability of the Egyptian surveyors is evident in his cited boasts about his own mathematical accomplishments that “not even the ‘rope-stretchers’ in Egypt excelled him.”

The period from about 400 B.C. up to the death of Alexander the Great in 323 B.C. is referred to as the Hellenic Age which produced such legendary Greek figures as Socrates, Plato and Aristotle, along with some other less well known men of numbers such as Theodorus of Cyrene, Eudoxus of Cnidus, Menaechmus – the reputed discoverer of the ellipse, parabola and hyperbola,, his brother Dinostratus – solver of the squaring of the circle, and Autolycus of Pitane (c. 320 B.C.) whose fame relates to him being the author of the oldest surviving Greek mathematical treatise entitled “*On the Moving Sphere.*”

8. ALEXANDER FOUNDS THE GREAT CITY OF LEARNING

332 B.C. saw the beginnings of events that would shape the future of the world, especially in the expansion and rapid advancement of science and the arts, with the ascension of the twenty (20) year old Alexander to the Macedonian throne after the assassination of his father Philip II

Before his march into Egypt Alexander had already conquered western Asia and the Levant, but his enormous respect for the Egyptians saw him embrace their culture and accept his recognition by the oracle of Amun-Ra as the god’s son, thus restoring the true pharaonic line in the country. Upon his departure from Egypt in 331 B.C. the City of Alexandria, which he had founded upon the ancient village of Raqote and named after himself, was already flourishing under his encouragement, and while he was off vanquishing the rest of the ancient world of the Persians and other races, as well as thriving during the later eras of the Ptolemies and Romans, it became the cosmopolitan centre of learning .

Populating his great school of learning at Alexandria (known as the Museum) with the greatest minds of his time, Alexander had conscripted the brilliant contemporary scholar, Euclid, author of the famous “*Elements*”, as a teacher there. Euclid was most praiseworthy for another of his peer geometers, Aristaeus, who had composed a treatise on conic sections

known as “*Solid Loci*.” When asked by King Ptolemy I whether there was a shorter way to learn geometry than to study the *Elements*, he said: “that there is no royal road to geometry.”

Archimedes of Syracuse (c. 212-287 B.C.) was an astronomer as well as a man of machines, following in the footsteps of his star gazing father, but, according to Otto Neugebauer, Apollonius of Perga, Pamphilia (southern Asia minor), who lived from 262 to 190 B.C., was “the founder of Greek mathematical astronomy”, and he also probably studied at Alexandria during his earlier years.

9. OF THE EARTH, THE SUN AND TRIGONOMETRY

Over fifteen hundred years before Copernicus proposed that the Earth revolved around the Sun instead of vice versa Aristarchus of Samos (c. 310-230 B.C.) put forward his hypothesis of a heliocentric Solar System in his treatise “*On the Sizes and Distances of the Sun and Moon*”, and he also made a calculation of the ratio of the distances from the Earth to the Moon and the Earth to the Sun. Despite the fact that his estimate was about 400 times in error, his method of determination was impeccable with the large error emanating from the inaccurate assessment of the angle subtended between the Earth, Sun and Moon when the Moon was approximately at a right angle to the Earth from its direct line to the Sun.

One of the most well known “men of Alexandria” was Eratosthenes of Cyrene who, after having studied in Athens and Alexandria, decided to settle in the latter in 255 B.C. He was soon after appointed the director of the great library there, and apart from working out a calendar which included leap years he also set about fixing the dates of political and literary history since the siege of Troy. His most celebrated act was the first calculation of the circumference of the Earth by observing the shadows cast directly down a well at Syene on the day of the summer solstice at noon then comparing this with the fact that at Alexandria (5000 stades away and assumed on the same meridian) at exactly the same time a shadow was cast indicating that the angular distance from the zenith was one fiftieth of a circle. Hence he derived a figure of 50 times the distance between the two towns which resulted in a circumference of 250,000 stades (25,000 miles/40,000 km), as compared to the modern value of 25,046 miles (40,074 km). He is also remembered for his “sieve of Eratosthenes” which isolates prime numbers systematically.

Earning the appellation of “The Father of Trigonometry” for his compilation of the first trigonometric table was the astronomer Hipparchus (c. 190-120 B.C.) of Nicaea, Bithynia (now Iznik in Turkey), and it is very likely that it was he who introduced the division of the circle into 360° due to his work on the table of chords. Menelaus of Alexandria (c. A.D. 100) is best noted for his introduction of spherical triangles contained within some of his works “*Chords in a Circle*”, “*Elements of Geometry*” and “*Sphaerica*”, the only work which has survived.

Claudius Ptolemy (85-165 A.D.) bore a name of mixed origins representative of the transition from the Grecian occupation of Egypt to the rule of the Roman Empire, from about 30 B.C. He is more renowned for his geographical work the “*Geography*”, in which he originates the

system of latitudes and longitudes as used currently, describes methods of map projection, and catalogues 8,000 cities, rivers and earth features. However, he also produced a monumental work in thirteen books commonly referred to as the “*Almagest*” (meaning “greatest”) published as the “*Mathematical Syntax*”, and cited as “by far the most influential and significant trigonometric work of all antiquity” by Boyer.

10. HERO OF ALEXANDRIA RECORDS GREEK SURVEYING

Even though there is extensive controversy about the precise dates of the birth and death of Hero (also known as “Heron”) of Alexandria the most plausible and convincing dates are a birth in A.D. 10 and a death about A.D. 75, just four years before the destruction of Pompeii in Italy ! He is most noted for the formula for the area of a triangle which bears his name:-

$$K = \sqrt{s(s-a)(s-b)(s-c)}$$

where a , b and c are the sides and s is half the sum of these sides

He is credited with writing treatises on many subjects entitled *Definitions*, *Metrica*, *Catoptrics*, *Mechanics*, *Pneumatics*, *Automata*, *Artillery*, *Cheiroballistra* and *Dioptra*. The work of the greatest significance to surveyors is his authorship of *Dioptra* as this describes in detail how to construct the Greek surveying instrument the dioptra in addition to setting out the various techniques for performing field surveying and remote distance measurement by triangulation. In his book “*Surveying Instruments of Greece and Rome*” M.J.T. Lewis includes a translation of Hero’s work *Dioptra* from the classical ancient Greek which lists the following instructions:-

- 1/ and 2/ Introduction to “the science of dioptrics”.
 - 3/and 4/ Instructions on how to construct a dioptra instrument.
 - 5/ Instructions on how to produce a stave for measurement.
- From now on the solution of various measurement problems is detailed, but I will supply only the summary of the heading:-
- 6/ To observe the difference in height between two points or if their height is the same.
 - 7/ To draw a straight line by dioptra from a given point to another invisible point, whatever the distance between them.
 - 8/ To find the horizontal (pros diabeten) interval between two given points, one near us, the other distant, without approaching the distant one.
 - 9/ To find the minimum width of a river while staying on the same bank.
 - 10/ To find the horizontal interval between two visible but distant points, and their direction.
 - 11/To find a line at right angles at the end of a given line, without approaching either the line or its end.
 - 12/ To find the perpendicular height of a visible point above the horizontal plane drawn through our position, without approaching the point.

- 13/ (a) To find the perpendicular height of one visible point above another, without approaching either point.
- (b) To find the direction of a line connecting two points, without approaching them.
- 14/ To find the depth of a ditch, that is the perpendicular height from its floor to the horizontal plane either through our position or through any other point.
- 15/ To tunnel through a hill in a straight line, where the mouths of the tunnel are given.
- 16/ To sink shafts for a tunnel under a hill, perpendicular to the tunnel.
- 17/ To lay out a harbour wall on a given segment of a circle between given ends.
- 18/ To mound up the ground in a given segment of a spherical surface.
- 19/ To grade the ground at a given angle, so that on a level site with the shape of an equal-sided parallelogram its gradient slopes to a single point.
- 20/ To find a point on the surface above a tunnel so that a auxiliary shaft can be sunk.
- 21/ To lay out with the dioptra a given distance in a given direction from us.
- 22/ To lay out with the dioptra a given distance from another point, parallel to a given line, without approaching the point having the line on which to lay it out.
- 23/ to 30/ The first five chapters refer to the dioptra setting out irregular shaped plots of land, while the remaining three explain how to determine the areas from those figures.
- 31/ To measure the discharge or outflow of a spring.
- 32/ and 33/ Describes how to utilize the dioptra in a vertical mode for the purposes of astronomical observations.
- 34/ This chapter informs the reader about the usage of another measuring instrument called the odometer, which has a device fitted to the wheels of a carriage such that the horizontal distance is evaluated in a very similar fashion to which a modern day perambulator gives distance.

Fortunately, Hero left to us through his writings this comprehensive compilation of instructions on how the Greeks were able to compute distances in many varied situations, as well as detailing the construction of the surveying instruments themselves, and I now leave it to two ancient Greek historians to highlight Greece's legacy of geometric and surveying knowledge from the practical applications originated by the Egyptians.

11. THE TWO GREEK HISTORIANS CHRONICLE GREECE'S DEBT TO EGYPT

Around 450 B.C. the first historian, Herodotus (c. 484-430/420 B.C.) of Halicarnassus (now Bodrum, Turkey) gave us the first memorable record of what the early Greeks had obtained from Egypt:-

"Sesostris,...made a division of the soil of Egypt among the inhabitants...If the river carried away any portion of a man's lot... the King sent persons to examine and determine by measurement the exact extent of the loss...From this practice I think geometry first came to be known in Egypt, whence it passed into Greece."

Over 400 years later it was the turn of Strabo of Amaseia (now Amasya) in Pontus, (c. 64/63 B.C.- A.D. 24) to echo his ancestor's statement when he said in about 25/24 B.C. while he was in Egypt with the prefect Aelius Gallus that:-

“An exact and minute division of the country was required by the frequent confusion of boundaries occasioned at the time of the rise of the Nile, which takes away, adds, and alters the various shapes of the bounds, and obliterates other marks by which the property of one person is distinguished from that of another. It was consequently necessary to measure the land repeatedly. Hence it is said geometry originated here.”

Despite the fact that Strabo was Greek, his city became part of the Roman Empire around the time of his birth, so even at that time the legacy of surveying knowledge from the Egyptians and Greeks onto the Romans was taking place.

12. CONCLUSION

In his paper in *The Journal of Egyptian Archaeology* of 1926 Sir Henry Lyons asserts that the knowledge extracted from the Egyptians was pivotal in explaining the “marvellous achievements of the Greek philosophers, accomplished within the singularly short space of four centuries.” He does stress that the Egyptian knowledge, especially regarding geometry, was propagated in a specifically practical way, but that the Greeks strived to provide a rational explanation of any phenomenon and the why and wherefore relating to it. Sir Henry further says: “ This difference between the Greek and the Egyptian type of mind seems to throw some light on the nature of the intellectual debt of Greece to Egypt.”

“Geometria” in its original literal sense meant the “measurement of the earth”, and even though the strict meaning of the word “geometry” underwent evolution through the teachings of the great Greek mathematicians into a more theoretical syntax of the mathematical applications of mensuration I shall conclude this paper with the motto adopted by the Institution of Surveyors New South Wales Incorporated (in Australia) which was the same as that erected on the portals of Plato's Academy, which can equally be applied to the Profession of Surveying:-

“Only those skilled in Geometria may enter.”

DEDICATION

This paper is warmly dedicated to the people of Greece in commemoration of the return of the Olympic Games to its place of origin in the Year 2004 and especially as a tribute to all of those brilliant ancient surveyors who so expertly carried out the survey work for the ancient civilization who have been immortalised in the magnificence of the ancient monuments which have stood the test of time and nature for thousands of years.

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Note: JARCE stands for Journal of the American Research Center in Egypt.

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APPENDIX A

Ancient Egyptian Dynasties*

Dynasty	B.C.	Period
30	380-343	Late Period
29	399-380	
28	404-399	
27	525-404	
26	672-525	
24/25	747-656	Third Intermediate Period
22/23	945-715	
21	1069-945	
20	1188-1069	New Kingdom
19	1295-1188	
18	1552-1314/1295	
14-17	1674-1553	Second Intermediate Period
13/14	1785-1633	Middle Kingdom
12	1991-1785	
11	2040-1991	
11 (Thebes)	2160-2040	First Intermediate Period
9/10	2160-2040	
7/8	2200-2160	
6	2460-2200	Old Kingdom
5	2510-2460	
4	2625-2510	
3	2700-2625	
2	2925-2700	Early Dynastic Period
1	3150-2925	

(*dates taken from Grimal, N., *A History of Ancient Egypt*, reprint 1995)

APPENDIX B

Ancient Egyptian Dynasties*

Dynasty	Ruler	B.C.	Period
Macedonian	Alexander the Great	332-323	Ptolemaic
	Philip Arrhidaeus	323-317	
	Alexander IV **	317-310	
Ptolemaic	Ptolemy I Soter I	305-285	Period
	Ptolemy II Philadelphus	285-246	
	Ptolemy III Euergetes	246-221	
	Ptolemy IV Philopator	221-205	
	Ptolemy V Epjphanes	205-180	
	Ptolemy VI Philometor	180-145	
	Ptolemy VII Neos Philopator	145	
	Ptolemy VIII Euergetes	170-116	
	Ptolemy IX Soter II	116-107	
	Ptolemy X Alexander I	107-88	
	Ptolemy IX Soter II (restored)	88-80	
	Ptolemy XI Alexander II	80	
	Ptolemy XI Neos Dionysus (Auletes)	80-51	
	Cleopatra VII Philopator	51-30	
	Ptolemy XIII	51-47	
	Ptolemy XIV	47-44	
	Ptolemy XV Caesarion	44-30	
Augustus to Eugenius		30 B.C.- A.D. 395	Roman Period

(*dates taken from Shaw, I., and Nicholson, P., *The British Museum Dictionary of Ancient Egypt*, reprint 1995)

** only titular ruler 310-305 B.C.