MYCENAEAN LESSONS OF DESCRIPTIVE GEOMETRY SHOWING CAM MECHANISMS TO MOVE HUGE BLOCKS

RAFFAELE SANTILLO
ARCHITECT, LUND INSTITUTION OF TECHNOLOGY

SUMMARY OF MECHANICAL ASPECTS [1]

The huge block of the Atreus Tholos Tomb at Mycenae weighes 120 metric tonnes, that is 120 middle-class european cars or three modern armoured tanks.

On the plain, the total passive resistance under a condition of sliding is the friction at rest, or static friction, which is developed during the interval leading up to impending slippage ; while slippage takes places, a condition of kinetic friction accompanies the motion.

Since the maximum static friction force is greater than the kinetic one, (about the double, between lubricated hard timbers), the moving power was supplied by relatively few men, some pushing at the "stem" up to an istant after slippage occurs, some at the same time tugging ahead and then towing along the pull.

The machine used at the back of the block was a wedge-type cam mechanism, (and not a lever) ; in Fig. 1a), a beam hinged at P (the mover), coupled with a wedge acting upward, Fig. 1c), "splits" the hinge and the profile-s-(the follower), Fig. 1b). Such a device could thus generate great forces increasing two-fold the (two) mechanical advantage, and horizontally convert the vertical pull of the men in an an enormous "take-off" force, (the greek word machine, in origin meant expedient ; in arabic haina, which means deceit, trick). The example of the monkey wrench, Fig.2, (which mechanically is not a plier even though they resemble each other), let clearer see whether the cam in the proper sense of the word or the wedge type variant.

The evidence ? The block at Mycenae shows two opposit inclined profiles at the longitudinal opposit ends, embodied within the double curvature of the internal chamber, statically a true cupola,[2] Fig.3-Fig.4. One could make an objection pointing the two profiles are an accidental case of working in the quarry ; but all the huge blocks in antiquity, positioned by other people all over the world, have the same wedge-shaped ends ! Moreover, at Mycenae, the different alpha inclination on the right end, and the beta on the left, Fig.4, show that the first was designed to go on uphill and the second for the plain route , ...as in all other huge blocks in the world ! Besides, in the Atreus Tomb the difference between the two angles of inclination is the double of the slope of the uphill route !

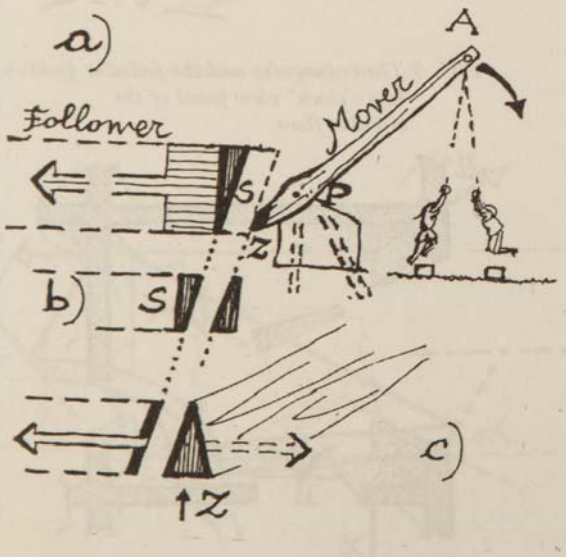

FIG. 1 The "expedient", or the "deceit". The mover and the follower : the cam mechanism.

Retracing their steps on the base of the last parameter, I was enabled to find the mycenaean quarry after 35 centuries.

An observer standing near the center of the tomb, turning his head and his eyes, or the objective axis of the camera, and pointing them towards the block-ends, gains the images previously described, Fig.3-Fig.4.

If he (or we) shifts bottomwards toward the right or left side, (that is toward four or eight o' clock of the circular floor), he gains a quite different image. Let's see why.

As the internal shape of the tomb is ogival, the acute (at) and the obtuse (ob) corners of the wedge-shaped ends rest on two circumferences, Fig.3, Fig.4, at different heights and therefore of different diameter : the W lines (profiles) which connect them soar in the internal space, and while resting on the ogival surface, bend toward the midst of the chamber.

Since this is a three-dimentional problem, it is convenient to refer to three coordinates of single view drawings, Fig.5, Fig.6 perspectives.

Here the eye in A sees the soaring pole inclined on the left, the eye in B sees it inclined on the right.

Thus if we draw an elevation, that is to say a right-angled projection with drawing plane parallel to the door, and therefore with observer's line of sight parallel to the stomeion-dromos axis, Fig.5 A, Fig.7, the two profiles of the opposit ends of the block will now converge upward.

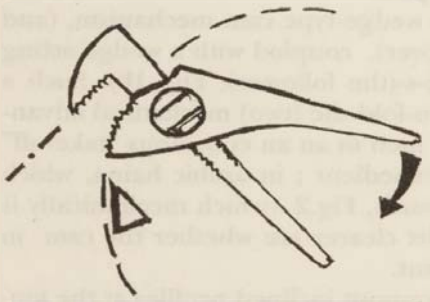

FIG. 2 The monkey wrench mechanism, with the pivot out of the center of the circular circumscribing profile : the cam.

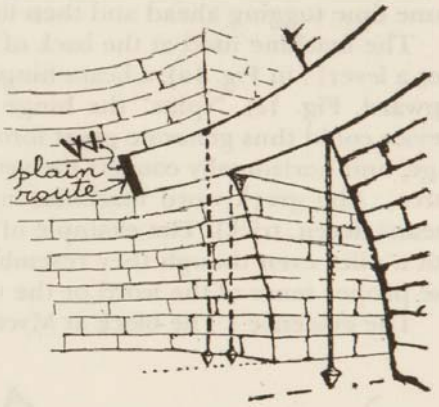

FIG. 3 The curvatures and the follower from "two o'clock" view point of the circular floor.

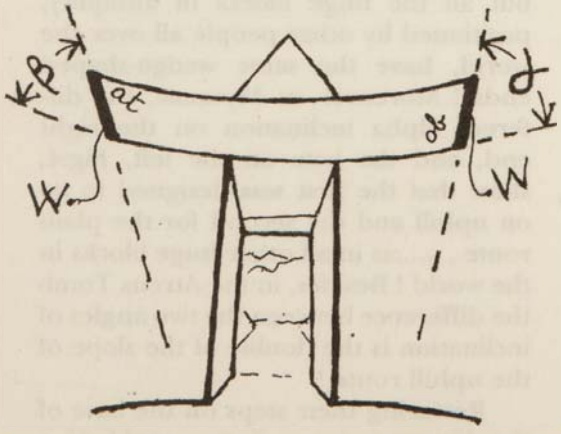

FIG. 4 The block opposit ends, single view point in the center of the Tomb.

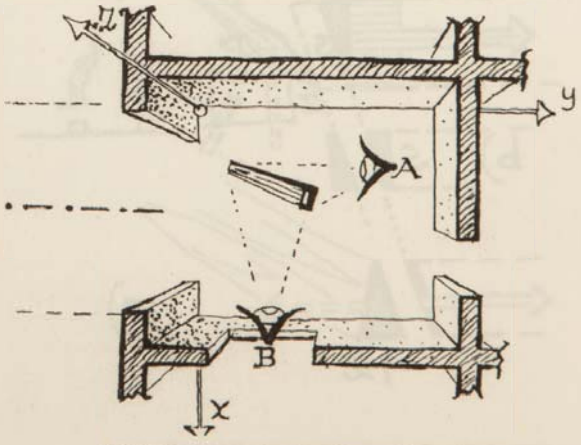

FIG.5 The two inclinations of a pole, from A and B.

Unless the block shape is a huge "triangular" sector in plane, Fig.8, the hidden ends should have edges more or less parallel to the stomion axis and consequently the end faces converging upwards.

On the other hand, such upward converging shapes, are meaningless from the transport point of view : no congruence between geometry and mechanical reasoning is here synonymous of nonsense!

Therefore, bearing in mind that the wedge shaped profiles are still extant and deserve an explanation, the sole logical shape of the hidden ends of the block is that in Fig.9, with profiles as inclined as the corner-edges facing the chamber ; these corner-edges, consequently, had no mechanical use but to acquaint us with something.

In fact the above reasoning that has now demanded the spatial imaginative procedure of the *Descriptive Geometry*, points out that the Mycenaeans intentionally left these symptoms in the masonry which could become signs in the mind of the visitor, sealing them by the most available and durable writing mean :"engraving".

Besides, they left a huge block in the north wall of the dromos, emphasizing the message with its inclined end profile and the saddle for the ropes, Fig.10.

The thing suggests itself : they wanted to show us not only the way they performed the job, but also that their procedure was strictly rational and did not rely on what today is commonly and wrongly called "rule of thumb".

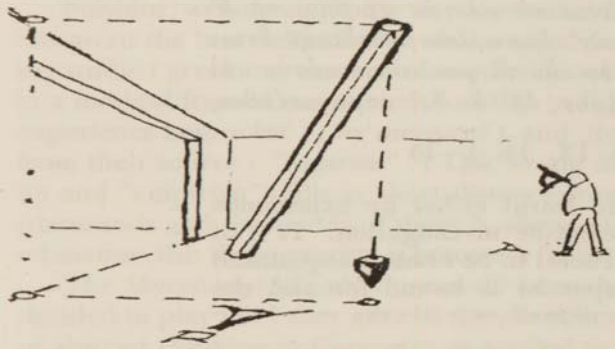

FIG. 6 The inclination of a pole from B.

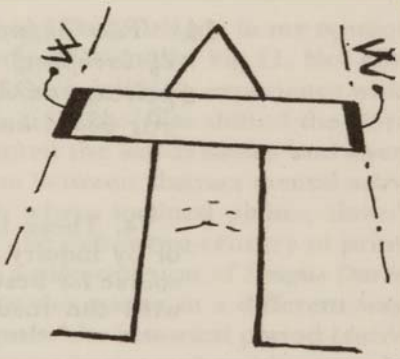

FIG.7 Elevation with drawing plane parallel to the door. The end profiles converge upward.

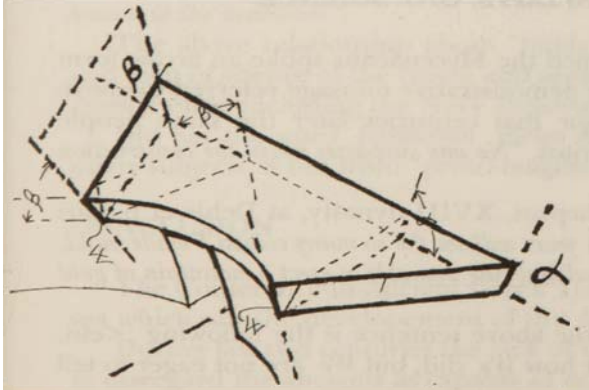

FIG. 8 The shape of the block congruent only with the profiles facing the chamber.

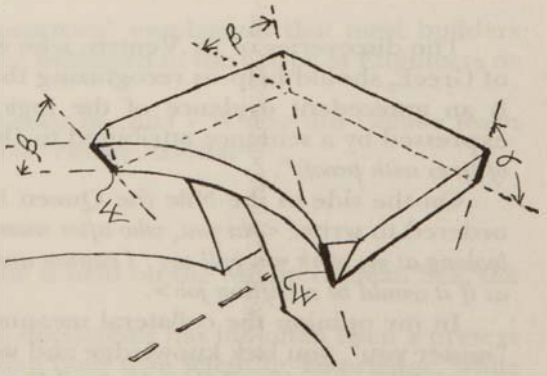

FIG. 9 The shape congruent with mechanism. Descriptive Geometry and message.

FIG. 10 The huge ashlar block facing the dromos and its follower.

THE HISTORIES OF POLYBIUS

14 Τῶν δὲ προειρημένων τὰ μὲν ἐκ τριβῆς, τὰ δ' ἐξ ἱστορίας, τὰ δὲ κατ' ἐμπειρίαν μεθοδικὴν θεω-
2 ρεῖται. κάλλιστον μὲν οὖν τὸ γινώσκειν αὐτὸν καὶ τὰς ὁδοὺς καὶ τὸν τόπον, ἐφ' ὃν δεῖ παραγενέσθαι,

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14. These things are learnt either by experience or by inquiry or by scientific investigation. It is of course far best for a general to be himself acquainted with the roads, the spot he is bound for and the nature of the ground as well as with the people by

FIG. 11 Polybius; an activity is scientific when "kata ..... empirian" .... !

MYCENAEANS AND EGYPTIANS : TWO SPIRITS, ONE SCIENCE

The discoveries of Dr.Ventris, who explained the Mycenaeans spoke an arcaic form of Greek, should help us recognizing that the demonstrative message referred to above is an antecedent evidence of the logical rigor that centuries later the same people expressed by a sentence attributed to Demokritos, "*No one surpasses me in the construction of lines with proofs*".

On the side of the Nile the Queen Hatschepsut, XVIII dynasty, at Dehir el Bahari ordered to write: <*ehi you, who after numberless years will see the so many colossi I made build, looking at my work you will say : I cannot understand how She was able to erect a mountain of gold as if it would be a trifling job*>.

In my opinion the collateral meaning of the above sentence is the following :<ehi, "mister you", you lack knowledge and wonder how *We* did, but *We* are not eager to tell you anything,.... it's..." *Cosa Nostra* " !>.

Given this way of thinking, there is no monument in Egypt which reveals technical features as clearly as at Mycenae.The paintings of Tehuti Hetep's Tomb, thow fascinating and very rich in details, conceal a trap in which scholars still to-day fall.[3] At Ninive,

where unsurpassed bas-reliefs decorated the royal palace, how many were the mycenaean-greeks in respect of other "emigrant-soldiers" working forces?

When Herodotos wrote <*for I hold that no man knows about the gods more than another; and ....*>[4] , he expressed his opinion without awe of the priests, in a country of travellers and islanders with their dynamic classes ; meanwhile south of the Aegean Sea Egyptians were keeping on the same rituals from millennia within an hermetic hierarchy that we find again in their former greek pupil and "immigrant" Pythagoras : the barrier of the Nile with educated people gathered in a caste, daughter and mother of the dogmas.

THE LONGUE DURÉE

Looking at the past it is in general possible to notice the everlasting existence of the two ways of thinking seen above.Their respective ups and downs belong < *to a history whose passage is almost imperceptible, that of man in his relationship to the environment, a history in which all change is slow, a history of constant repetition, ever-recurring cycles* >;.....< *On a different level from the first there can be distinguished another history, this time with slow but perceptible rhythms* >.[5]

In the Bible the Almighty says: < *I must go down and see whether deeds warrant the outcry which has reached me. I am resolved to know the truth* >[6].

The above associated verbs *to see* and *to know*, became *again* linked phases with Galileo when He first looked and then *saw* through the telescope to *Know* the objective *truth* ; finally He explained by and with reasoning.

Polybius, writing about the way a commander should get knowledge,[7] in my opinion has given the best definition of what a scientific knowledge was and is, Fig.11. Not having studied greek, my macaronic translation sounds < by inquiry *or by* experience within a method framed in a theory >, while in Fig.11 the translator has shifted the word experience before *kat'* , (by means of), and thus disjointed the words *method* and *theory* from their source : *"empirian"* ! ! This wrong dissociation between abstract mental activity and "empirian", falls at short distance from the pit where inclined planes, slaves[8], (thousands and thousands of them !), aliens! (Incas,etc) lie ; after two century of printed matter this degeneration is become a "third way" of a phenomenon of *Longue Durée*.

The Mycenaens, if only they could know how to put the matter in a different way, decided to play fair ; they gave us the possibility to lenghten the historical period (*durée*) of abstract thinking in Geometry as applied to elementary physics and architecture, by shifting its bench mark one thousand years backward from classical times.

Revealing a hidden technical feature by the above design, they make the words of Gaspard Monge live again after three thousand years, < *in this sense it* (the Descriptive Geometry) *is a mean of scientific research ; it offers continuous examples of passage from the known to the unknown* [9].

The above relationship about "hidden Geometries" emphasizes that most builders and men of science of the recent and ancient past belonged to the Corps of Engineers or *Zamu*,[10] often including the Navy Department.

Did not the word *Architecton* mean ship-builder in chief ? Where did Galileo learn many subjects, if not from "proto-magistri" in the Venice Arsenal[11]?

CONCLUSION

The Conference in Ancient Greek Technique is held on the Mediterranean Sea, the sea which saw the developement of this Art.

During last two centuries the lack of written documents has too often been a pretext to disregard the ancients as capable of developing their own scientific knowledge, while "scientific modern men", the "fifth column" of the *Durée*, are not yet able to reveal how they built outstanding monuments of the past :

< *If the Mediterranean has done no more than force us out of our old habits it will already have done us a service* >[12]!

NOTES

1. Santillo, R.,
   a-«Abstract of 89 A.I.A.Meeting», New York 1987, in *A.J.A* n 92.
   b-*Il Blocco da 120 Tonnellate a Micene, Edilizia Militare, (Italian Corps of Engineers Review)* n 25-26, GenioDife, Roma 1989.
   c-*Il Blocco da 120 Tonnellate a Micene, con la soluzione del trasporto a terra e posa in opera per gli altri massi dell antichita. Archeologia*, n 1-2, GAI, Roma 1990.
   d-*Il <Saxum Ingentem > a Ravenna a Copertura del Mausoleo di Teoderico*, (with an abstract in English), *Opuscula Romana*, XX, Stockholm 1996.
2. Santillo, R.,
   a- *The construction and structural behaviour of the Mycenaean Tholos Tomb, Opuscula theniensia*, vol. XV,Uppsala 1984.
   b-*Le cupole a secco*, Edilizia Militare, n 17-18, GenioDife, Roma 1986.
   Frizell, B.S., «The true Domes in Mycenaean and Nuragic Architecture», *BAR* intern. Series 387, Oxford, UK, 1987.
3. *Technology and Culture*, vol II, n 1 winter 1961, Chicago University, C. Davison, *Trasporting Sixty ton Statues in Early Assyria and Egypt.*
   The author, «assumes» 120 pounds, which is three times the pure pulling force of a man, and almost that of a horse ! Then he multiplies the «assumption» and exactly «rescues» the Tehuti-Hetep painters and his120 pounds ! This is filibustering.
4. Herodotus, Book II.5, Loeb Classical Library translation.
5. Braudel, F., *The Mediterranean and the Mediterranean World in the Age of Philipp II*, Fontana Press; abstract from preface.
6. *Genesis*, 18,21, 22, (Sodomah and Gomorrah).
7. *The Histories of Polybius*, Book IX., 14. 1-3, Loeb Classical Library translation.
8. For «slaves» see note 1; for the impossibility to consider the inclined plane a simple machine, see note 1 and my review at pag. 12-14 in *SAS* Bulletin, Harvard University, volume 16, number 1, Lancaster January-March 1993, PA, USA.
9. Monge, G., *Leçons de géometrie descriptive*- Ecole Normale Supérieure, Paris 1795; my translation from the italian text Bompiani-Longo, Geometria Descrittiva, Roma 1959.
10. Zamu, name used in Egypt, (see note 1c and 1d). Living out the last two wars, Coulomb, Carnot, Menabrea, Sana, Agrippa, Architas, Archimedes, Odysseus, Imothep etc. etc. were officer of Corps of Engineers.The modern greek name is Stratiotis Mechanicou.
11. See Galileo's first page of *The New Sciences* (Le Nuove Scienze), and note 1 c.
12. Fernand Braudel, see note n 5 above.

ΠΕΡΙΛΗΨΗ

ΜΥΚΗΝΑΙΚΑ ΠΑΡΑΔΕΙΓΜΑΤΑ ΠΕΡΙΓΡΑΦΙΚΗΣ ΓΕΩΜΕΤΡΙΑΣ, ΠΟΥ ΔΕΙΧΝΟΥΝ ΕΚΚΕΝΤΡΟΥΣ ΜΗΧΑΝΙΣΜΟΥΣ ΓΙΑ ΤΗ ΜΕΤΑΚΙΝΗΣΗ ΤΕΡΑΣΤΙΩΝ ΟΓΚΩΝ

R. SANTILLO

Η απαιτούμενη ισχύς για τη μεταφορά της λίθινης πλάκας 120 μετρικών τόνων, που καλύπτει το στόμιο του Τάφου του Αγαμέμνονος, προσφέρθηκε απο λίγους σχετικά άνδρες. Αυτό έγινε με τη βοήθεια ενός έκκεντρου μηχανισμού, σαν ένα είδος σφήνας (wedge-type cam mechanism), ο οποίος μπορούσε να παράγει μεγάλες δυνάμεις.

Οι κεκλιμένες κατατομές των τεράστιων αρχαίων λίθινων όγκων έχουν ενσωματωθεί μέσα στη διπλή κυρτότητα του πραγματικού θόλου. Περιγράφοντας τα εν λόγω στοιχεία θα λέγαμε πως πρόκειται περί "βιρτουόζου" της αρχιτεκτονικής του χώρου. Το γεγονός αυτό δείχνει ότι οι Μυκηναίοι σκόπιμα άφησαν τα συγκεκριμένα σήματα και μηνύματα πάνω στη λιθοδομή των τοίχων, για να δείξουν στις επόμενες γενιές ότι η μέθοδός τους ήταν αυστηρά ορθολογική και δε βασίστηκε σε σύλληψη που κοινώς αποκαλείται "εμπειρική".

Στη φράση που αποδόθηκε στο Δημόκριτο, "Κανείς δε με ξεπερνά στην κατασκευή γραμμών με αποδείξεις", καθώς και σε μερικές φράσεις του Πολύβιου, φαίνεται η αυστηρότητα του ορθού λόγου. Η τελευταία αποτελούσε ήδη στοιχείο της Μυκηναικής-Ελληνικής νοοτροπίας που άκμασε εκ νέου κατά την εποχή του Γαλιλέου.