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The Technology of Land Reclamation, Drainage and Irrigation Projects in MBA–LBA Greece and Possible Implications

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Abstract

Technology and its "products", when unearthed from archaeologists, are irrefutable witnesses of the technological level of each era and place. Evaluation of archaeological finds in relation to the advanced technology of each era and compared to the ancient literature, could infer conclusions regarding the nature of relations between different civilizations. Metallurgy, construction technology and know-how (structures, flood-control works, Land Reclamation, Drainage and Irrigation works etc.), production and exchange of precious metals, silver and iron, as very rare metals, constituted "cutting-edge technology" for the Middle and the Late Bronze Age. In prosperity periods –of excessive wealth– the "Arts and Engineering" flourish, an advanced know-how in constructions is developed and monumental projects are launched. The examination of the technological level in (monumental) constructions and hydraulic works of Middle Bronze Age – Late Bronze Age (MBA, ca. 2200/2100-1580 B.C. – LBA, ca. 1600 – 1100 B.C.) Greece, and the environment that was shaped, as it is implied by the material evidence, could infer implications for the historical canvas of the period. There is a debate surrounding Technology and its "flow", its nature and origins. Some researchers support the spread of innovation from East to West, and a contradictious aspect of cross-fertilization or diffusion between East and West. In the present study, a combination of the archaeological evidence (both material and textual) of the technological level in constructions –especially in MBA and LBA Greece– and metal production, the ancient literature, the written sources, is attempted, in order to infer conclusions for the Technological, environmental, cultural and socio-economic aspects regarding possible relations and exchanges of Technology among Minoan Crete and/or Mycenaean Greeks -Danaoi/ Achaeans, as Homer calls them- with Egypt and the land of Hatti, specifically during the Middle and Late Bronze Age.

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1. Introduction

The period of the great expansion of Mycenaeans abroad and the opening of the commercial routes to the Black Sea is followed by a huge "investment" in monumental structures, great scale projects and extravagant grave goods serving for afterlife prestige. It infers also a period of high prosperity in Mycenaean Greece of that era. This implies that, during this period, Mycenae was the heart of a flourishing kingdom. This period of excessive wealth with monumental construction projects, leads to the further development of advanced know-how and cutting-edge technology, in Engineering, and characterizes –in general– all the Great Powers in History (Giannakos, 2012; 2013; In-Press). The know-how of cutting edge technology in Minyan, Minoan and Mycenaean Greece in: design and construction of buildings and Drainage and Land-Reclamation works co-exist with the know-how of metals' production in silver, iron and bronze as it will be depicted in the present article.

2. Prosperity Period for Palatial Centers in MBA–LBA Greece

Mycenae grew in significance in Middle-Helladic III (MHIII, ca. 1700-1580 B.C.) - Late-Helladic I (LHI, ca. 1580-1480 B.C.) periods (Giannakos, 2012; Voutsaki, 2005), when an exclusive concentration of wealth in the Mycenaean Shaft Graves is recorded (Voutsaki, 2001). The grave goods of that period provide assemblages of material culture indicating levels of prosperity, social complexity and artistic influence. Wealthy societal groups also emerged (Shelton, 2012). Grave Circle A (ca. 1600-1500 BC), Grave Circle B (ca. 1650 - 1550 BC) and their rich contents show an "*emerging elite*" in Mycenae (Colburn, 2007). The sudden accession to great wealth indicated by the findings from the Shaft Graves is a proof of the likely Mycenaean military prowess in this period. Moreover, LHIIIA2 (ca. 1380-1310 BC), is the great period of Mycenaean impact and expansion on the coast of Anatolia and Dodecanese (Wiener, 2007) and, of close relations with Egypt. French (2012) states that "*the most striking feature of the MH period, in Mycenae, is the clear growth of wealth, apparent in the burial evidence of Grave Circle B, since at the end of the period, Mycenae becomes one of the most important sites of Argolid and its leaders enjoy a clear degree of preeminence*".

Pylos -in LHIIIA (ca. 1440/1420-1340 B.C.)- developed the network of taxation and workshop centers supporting it (Shelmerdine, 2001). This highlighted the peak period for the deposition of wealth in tombs, the highest number of rich tholoi, where[1], large number of prestige items of very high quality and even some unique pieces were found. In Thebes, from MH/LHI to LHIIIA1 and early-LHIIIB1 (beginning ca. ~1340 B.C.)there is evidence of local manufacture of glass, jewelry, gold jewelry and inlays at the House of Kadmos, kiln and workshop (Dakouri-Hild, 2005).

Cavanagh (2008) mentions that by LHIIIA, richer tholoi seem to go out of use in Argolid except of Mycenae and Messenia, probably due to the fact that the smaller powers were swallowed up by the central palaces. French and Shelton (2005) support that, these tombs were built by the elite or high-status families of Mycenae at LHIIA. In Argolid, the tholos tombs flourished with a rather brief span of use. It becomes clear that Mycenae displayed an enormous range and quantity of funerary offerings of the highest quality[2]. The golden foil ornaments and beads are found, besides Mycenae, in all larger sites in Argolid in LHII (ca. 1580-1440/1420 B.C.)- LHIIIA period[3]. Mycenae grow in significance in MHIII - LHI periods. The wealth of the aristocracy was sheltered in graves of highly technological achievements. The wealth of the graves, at Mycenae, is unique, in the MHIII - LHI period and the entire southern mainland witnessed a general increase in prosperity, as well as increasing interaction with the Aegean. Furthermore, in the MHIII - LHI periods a new mode of social evaluation was introduced, based on ostentatious practices[4] and possibly military achievements (Voutsaki, 2005).

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[1] As in the Shaft and Chamber Graves, in LHII/LHIIIA-B, Voutsaki, (2005).

[2] Voutsaki, (2005): "*Certain types of objects remain exclusive to Mycenae: the golden masks, animal rhyta, electron vase, faience conch shell and sacred knots or the solid elaborate jewelry etc. found in graves*".

[3] Voutsaki, (2001); French and Shelton, (2012), cite that not every site in Argolid in LHII-IIIA1 featuring a tholos tomb had a palace necessarily, fact that implies, a wide use of the tholoi not only by the Kings of central palatial powers (Mycenae, Pylos) but also by the minor kings, at this period.

[4] e.g. conspicuous offerings at graves.

At this period the engineering achievements in design and construction reaches at the highest level: *The tholos tombs -but Shaft and Chamber Graves also- are the landmark for the families of Kings and aristocracy, where their members are laid with precious objects. "Conspicuous consumption" is evident in the construction of the tholos tombs. When the Treasury of Atreus* (Fig. 1) *was built, houses were demolished, thousands of tons of rock and rubble were excavated and removed, blocks of limestone and conglomerate were quarried and carted in, fine stones were shipped from other parts of Greece and skilled craftsmen worked for many months to finish it, requiring tens of thousands of man-days in expediture of effort". This implies a huge amount of capital to be spent for the "luxurious" structures, and the precious, valuable gems in them that "were retired" from circulation of every-day life and effectively "destroyed" for the living, suggesting not just a piety to the memory of the dead, but prestige to the family* (Cavanagh, 2008; Voutsaki, 2012).

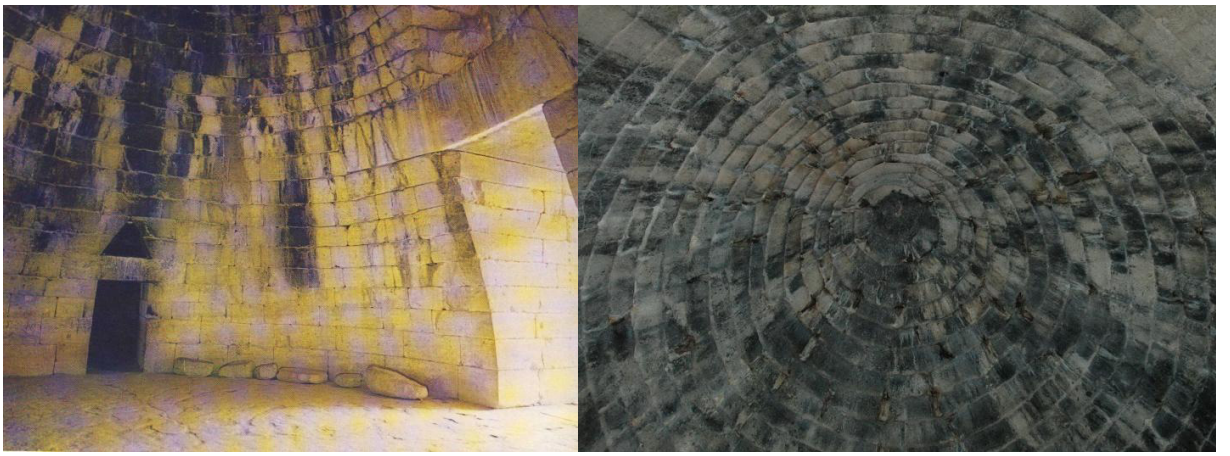

Fig. 1: Atreus' Treasury: perfect fitting of the stone-blocks in the joints, where not even a paper-sheet can intrude, depicting the cutting-edge technology and know-how in Mycenaean Greece [photos by author].

French (2012) believes that: *the works of the (re)construction of megaron at Mycenae ("maison de chef") and the Treasury of Atreus were performed by a -perhaps- corvèe workforce and this well accords with the strong evidence of overseas expansion of Mycenaean culture in the period of 14th to 13th centuries*. In general, an extraordinary increase of the population, in the LHIIIA2 (ca. 1400-1340 B.C.) and LHIIIB (ca. 1340-1200 B.C.) periods, now documented, especially for the Argolid and Corinthia and for parts of Boeotia and Messenia, made the construction of these great construction projects not only possible but necessary (Hope-Simpson and Hagel, 2006).

This is also the period of the great expansion of Mycenaeans abroad and the opening of the commercial routes to the Black Sea. This huge "investment" in structures and extravagant grave goods serving for afterlife prestige implies also a period of high prosperity in Mycenaean Greece of that era. This implies that, during this period, Mycenae was the heart of a flourishing kingdom[5]*. This period of excessive wealth led to monumental construction projects, demanding the further development of advanced know-how and cutting-edge technology, in Engineering*[6]*.*

In prosperity periods –of excessive wealth– the "*Arts and Engineering*" flourish, an advanced know-how in constructions is developed and monumental projects are launched (Giannakos, 2013).

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[5] For the decline period in palatial centers see Giannakos, 2012; 2013.

[6] Tassios, (2011), writes that "*Μηχανή*"/"Machine" or in Doric Greek "*Μαχανά*", from which the Greek word for "*Engineer*"/"*Μηχανικός*" is produced, is the -beyond Nature- amplifying factor of human abilities. Plato and Aristotle are "*φίλοι*"/friends to Technology as we can discover in Plato's "Protagoras", §321c,d, 322a,b,c, "Filivos", 55E, "Politeia", 600a and in Aristotle's "Ekonomic", VI, 5, "Politics", 1253b, 34 and "Mechanics", 847a. Tassios, (2001), also, ascertains that Mycenaeans were surprisingly advanced in structural, hydraulic engineering and metallurgy, in their gods Hephaestus was comprised, a god-engineer. The creation of humans by God was carried out by a trial-and-error method, the first and fundamental connection was the donation (to the humans by the gods) of "technical knowledge" and "energy" and their Mythology since the very beginning was dominated by automats (e.g. Daidalus) and robots (e.g. Talos). In Tassios (2006), for continuous interaction between science and technology.

3. Technology and Know-how of Mycenaeans, Minyans and Minoans

3.1. Structural "Engineering"

Minyan, Minoan and Mycenaean Greeks had advanced cutting-edge technology and "engineering" know-how, from the beginning of the early MH (begins: ~2200/2100 B.C.), or even earlier. Almost every settlement, since neolithic times, used 2-meter thick fortification walls from the mid-third millennium already, in Lerna, ~2500 B.C., Syros, ~2200 B.C., Aegina, ~2100 B.C., (Palyvou 2005a; Tassios, 2008). By the LMIA the ashlar wall technology was very popular in all houses in Akrotiri and Crete (Palyvou 1999). The bearing capacity of a stone wall increases with the width. This is a technical know-how gained from experience, or trial-and-error method[7]. It was very normal to develop -one thousand years after the mid-third millennium- 3m-thick walls at Tiryns and 5m or 7m in Mycenae even later (Tassios, 2008; Palyvou, 2005a). This procedure of gradual development of a wall's bearing capacity, by increasing its thickness, is very simple know-how for "engineers": they had to move apart a little the external masonry sides and increase the "filling" inside, in order to undertake higher loads. However a really intuitive engineer's spirit is needed, to design and construct a structure to bridge great openings: the three-dimensional corbelled vault used for tholos tombs. In this case a really original know-how and very high technological level of knowledge and skill is demanded. *Mycenaean "Engineers" utilized very successfully the coursed ashlar in the construction of large bee-hive tholos tombs with the corbelling technique* (Palyvou, 2009) and constructed adobe structures presenting strength in today's terms of 3-5N/mm^2, much higher than the strength (~3N/mm^2) of modern bricks of low quality[8]. Palyvou (2005a) states: "*The corbelling vault system, applied in the construction of these most impressive stone bee-hives, seems to function in parallel to the system of the successive rings, since the very thick layers of earth-fillings on the tomb, covering the protruding section of the vault, are necessary for the stabilization and the waterproofing of the structure*". The corbelled vault tholos at Fourni Crete belongs to EMII, ~2900-2300 B.C.[9], the know-how expanded at Messenia *where the first tholos tombs belong at late-MH* and at Kakovatos, at MH or early-LHI (Treuil et al., 1996). Smaller tholoi in Georgiko and Koryfasio are referred (Tassios, 2008). The tholos tombs at Mycenae have been constructed even before 1520 B.C., for the Kings and their close families[10].

The structural analysis of the "*Atreus Treasure*", with the Finite Element Method, calculated maximum tensile and compression stresses of approximately -0,74N/mm^2<-6,67 MPa and 0,17N/mm^2<2 MPa (Askouni et al., 2008), implying linearly elastic behavior with no damage expected. Similar results were derived from the structural analysis of the tholos tomb of Thorikos, Attiki, which are[11] "*emphasizing some of the intuitive choices made by the Mycenaean architects in those remarkable monuments*". For the dating of "Atreus Treasure", finds of LHIIIA1-LHIIIA2 are mentioned at the grave's "*dromos*", shreds of bothros deposit of the grave of LHIIIA1, testimonial that it was reused (Cavanagh and Mee, 1999). This provides a *terminus ante quem*.

The Minoan architecture was propagated beyond Crete (Shaw, 2009; Palyvou 2005b): at Akrotiri in Thera, Phylakopi in Melos (LMI or LCI), Trianda in Rhodes (LMIA), Pylos in Messenia, Menelaion in Sparta (LHII-LHIII), Mycenae and Tiryns, where the first Throne Room is dated at MH - LHI the latest, since the Great Megaron with the first fortification walls were constructed in LHIIIA during the early 14th century[12].

In Messenian Pylos, influenced by the highly Minoanized Kythera, some ashlar walls, found by Blegen, were identified by Klaus Killian as belonging to a Minoan or Minoan influenced "*Cretan*" structure, dated to LHII/early LHIIIA1. Of particular interest is a double-axe "*mason's-mark*", on the face of one block as well as the double axe signs engraved on the stomion blocks of the LHIIA tholos tomb at Peristeria. A gypsum frieze with triglyphs and

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[7] About the empirical and intuitive ability of Mycenaean "Engineers": Cremasco and Laffineur, (1999); Hope-Simpson and Hagel, (2006).
[8] Palyvou et al., (2001), for Akrotiri.
[9] Dickinson (2003): dated by Sakellarakis.
[10] Mylonas, (1983): "*Daimons's*", "*Atreus's Treasure*", "*Klytemnestra's*" tholoi.
[11] Cremasco and Laffineur (1999); Treuil et al., (1996): the tomb is dated between MH-LH. This implies an average date 1550 B.C.
[12] Papademetriou, (2001); Maran, (2012); Hope-Simpson and Hagel, (2006): *The Mycenaeans' skill in engineering was initially learnt from the Minoans*.

half-rosettes in Tiryns, the running spirals at the facade of the "Treasury of Atreus" and the Tiryns gypsum triglyph and half-rosette resemble similar elements from Knossos (Shaw, 2009).

For sewage and sanitary installations, systems of water traps and odor traps in palaces and town houses were unearthed in Akrotiri, similar to the ones used in modern houses (Palyvou, 1997). This technique was "forgotten" and re-used again, at the end of the 19th century AD.

The aforementioned material evidence is analysed also in connection with the fact that according to the ancient literature, the Walls of Troy were built by two gods Apollo, Poseidon and one mortal, the king of Aegina Aiakos, who had close relations to Cretans, the colonists of Troy. The Walls of Tiryns were constructed by *the Cyclopes* for *Akrisios*. Cyclopes, the smith-deities, were part of the pre-Olympian trinity "*Titans, Cyclopes, Hekatonheires*", in prehistoric Greece[13], and they were also the bearers of technology in the ancient Hellenic mythology. However we believe that, in this myth, Cyclopes "*gastroheirs-belly-hands*" represent labor-force "*invited*" to build the walls, following Strabo: "*Cyclopes who came by invitation from Lycia and gained their living from their handicraft*"[14].

3.2. Production of Silver and Iron

The technology and know-how of metals' production is of crucial importance since Silver and Iron much more valuable than gold. Furthermore the bronze's production is also the cutting-edge technology, which gave the name of bronze to a whole historic era. After the rebuttal of the old theory about the Hettitic monopoly (Sandars, 1978/2001; Muhly, 2006) of iron during the 2nd millennium BC, it could be inferred that iron was initially introduced and spread as a strange and luxurious metal and afterwards as a possible consequence of the real shortage of tin and even copper. The presence of silver in eastern EMI Crete is surprising (Muhly, 2008). *There was intensive exploitation, working and production of silver* and lead from Laurion area mines *from Late Neolithic, Early Bronze Age, Middle Bronze Age to Late Bronze Age*[15]. A cupellation workshop (Kakavogianni et al., 2006), from 2500 B.C., was excavated and hundreds of litharge fragments were recovered, with evidence of the process of silver separation from argentiferous lead. Specified quantities of metal were used as a medium of exchange in the pre-coinage societies (Michailidou, 2005; Michailidou, 2008).

Iron seal rings have been found at Dendra and Pylos containing nickel ranging from 2-11%, derived from meteorites or from nickel-bearing ores, as in Larymna, Euboea and Skyros (Varoufakis, 1999). Iron seal rings at the Archaeological Museum of Athens are dated from 15th-13th century BC. Iron -according to tablets from Akkad- was six times more valuable than silver (Varoufakis, 2005). It should be emphasized that iron -as an extremely precious metal- had already been used in Crete since the first half of 17th century BC, as the findings from a human sacrifice at Anemospilia –near Archanes– confirm, where the priest wore a silver ring that was iron-plated. Furthermore, iron has also been encountered in later Royal burials in Minoan Crete (Sakellarakis and Sakellarakis, 2002). There are also references for iron-gifts to the Pharaoh in Amarna tablets (Lucas, 1948; Moran, 1992; Ogden, 2000). After the rebuttal of the old theory about the Hittite monopoly of iron during the 2nd millennium BC (Sandars, 2001; Muhly, 2006), it could be inferred that iron was initially introduced and spread as a strange and luxurious metal and afterwards as a possible consequence of the real shortage of tin and even copper. In Tutankhamun's tomb, several iron objects were found[16]. It is characteristic that the first citation of T/Danaja (Δαναοί)[17] in Egyptian archives is dated on the 42nd year of Thutmose III's reign in connection to silver and iron objects (Redford, 2003): *"[Benevolence of the chief] **of Tanaya**: Silver: a jug of **Keftiu workmanship** along **with vessels of iron**[18]..... with silver handle(s) 4, making 56 dbn, 3 kdt".*The "*Keftiu workmanship*" in metallic objects is

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[13] "*Intellect, Technology and Natural Forces*", the "*equilateral triangle*" of the "*manifested deity*": Tassios, (2005); (2008); (2001).

[14] ***Gastroheirs-Γαστερόχειρες***. Str. Geogr. 8:6:11:1-4; Pseudo-Apollod. Bibl., 1:2:24:7–1:2:25:6.

[15] Muhly, 1997: Silver at Laurion was being exploited by the mid-third millenium BC. Stos-Gale et al., 1995: for Mycenaean/Minoan world, the main source for lead, silver and copper was Laurion. Stos-Gale (1982) supports that Laurion seems to be the predominant source of the finds in Shaft Graves at Mycenae.

[16] Coleman and Manassa (2007) refer that the iron-dagger found in the tomb was not made from meteoric iron; Lucas, 1948; Muhly, 2006; Ogden, 2000.

[17] T/Danaja (or Danuna) are most probably Δαναοί. This gift from Tanaya/Tinay was offered to Thutmose III at a time when the Pharaoh was campaigning against Tunip and Kadesh (Strange, 1980).

[18] Redford (2003), transliterates "iron" and refers to several articles (Harris, Ogden, Aufrere), about the rarity of such a manufacture. Breasted

also referred later in Pylos tablets: "*ti-ri-po-de ai-ke-u ke-re-si-jo we-ke*" transliterated as "*two tripod cauldrons of Cretan workmanship, of ai-ke-u type*". The aforementioned Thutmose's III description of the 15th century BC could point to Keftiu/Crete, during Tanaja sovereignty, as an iron-producing country. *The Keftiuan work was highly appreciated as it may be inferred from the fact that a work from Keftiu was given together with bowls made of iron, a priceless metal*" (Strange, 1980; Kelder, 2010).

Mycenaeans possessed the technology of bronze's production and they produced bronze weapons, swords and spear-heads. These swords are rare outside the Aegean area. They must have been tremendous weapons both in war and in hunting. Minoans and Mycenaeans did not trade their weaponry, seldom made presents of their swords, and those found far away could not be explained by trading. These weapons provided the military superiority to the Mycenaeans (Giannakos, 2012). The tin's supply to Mycenaeans still remains exists a matter of a widely discussed controversy, till today.

4. Land Reclamation, Drainage and Irrigation Projects in MBA – LBA Greece

Mycenaeans had also constructed Flood Control and Land-reclamation works at many sites in mainland Greece with most characteristic[19] of which, the "drainage" of Kopais lake near Boeotian Orchomenos and the flood protection works with the deviation of Alfeios river at ancient Olympia[20]. Flood protection works were also performed in LHIIIB, with a dam construction at Tiryns (Maran, 2012; Tassios, 2008; Hope Simpson and Hagel, 2006). For the Kopais lake works, Iakovides[21] reports that Spyropoulos[22] unearthed shreds of MH period (begins at 2100 B.C.), from the still existing today Mycenaean dams (Fig. 2). In his more recent work Spyropoulos (2013) refers that he and Laufer unearthed shards of EH (begins in the 3nd millennium B.C.) in these dams. These shards provide a *terminus post quem*. Tassios[23] refers that this advanced technology and the first phase of the works were developed since the middle of the 2nd millennium BC, and the second phase of the drainage systems constructed during the 14th and 13th century BC. Knauss (2002) dates the Kopais' works at the mid-second millennium BC with their apogee at 14th and 13th centuries BC, since a section of the levees is dated at MH period[24]. The flood control and land reclamation works at Kopais were achieved through a system of polders, combined with channels and dams (Figure 1)[25]. Hope-Simpson and Hagel (2006) refer: "T*he extensive remains (of the system of polders) belong mainly to the latest period of use i.e. LHIIIA2-B. Attempts may have been made to canalize the rivers in earlier Mycenaean times i.e. within the LHI to LHIIIA1 period, but the actual schemes of the canals are apparently no earlier than LHIIIA2 and radical in nature*".

According to Tassios (2008)[26]: "During that period, agriculture was the main wealth of Greek regions – whereas only a small part of soil was cultivable. Besides, most of this cultivable soil was located in closed valleys, flooded almost every year. Flood-control and land reclamation was therefore of a paramount importance for Mycenaean peoples. The advanced hydraulic technology they developed since the middle of the 2nd millennium BCE, is very impressive by its rationality, the large scale of its applications, as well as by its efficiency. Based on the examples of

(1906, vol. 2), transliterates also iron and writes "*By* □". Strange (1980) transliterates "iron" and for "*bi*□" quotes Harris and Graefe, who doubt if "bi□" in this case could be iron, although it evidently must be some metal; Cline (2009) and Panagiotopoulos (2009) transliterate iron (or copper (?)).

[19] For a detailled description of these -major scale- "*engineering*" works, see, Tassios, 2006a, 2006b, 2008, Knauss, 2005; 2002, Palyvou, 2009.

[20] For more details see Tassios, 2008; Knauss, 2002; Hope-Simpson and Hagel (2006) date LHIIIB and LHIIIC.

[21] Iakovides, 1997. Kountouri et al., 2012, refers: "Terminus ante quem for the chronological determination of the construction of the retaining wall is provided by the cemetery found at the site of Stroviki, which is located at a level lower than that of the foundation trench, and dates to the MH period", citing Aravantinos et al., (2006).

[22] Theodoros Spyropoulos -*in personal communication with the author on August 2011*- confirmed it and he added that it was published already in Σπυρόπουλος (1973). The excavation of Spyropoulos is referred also by Hope Simpson and Hagel, 2006: "*the 1973 excavation by Spyropoulos revealed some details of the structure of one of the walls of the canal bank*". Spyropoylos (2013, vol. I, 71) also refers that with Laufer, (1985, 101) excavated in Kopais pottery dated Proto-Helladic (3nd millennium BC).

[23] Tassios, 2008, p. 12, citing Iakovides, in the "*History of Hellenic Nation*".

[24] Knauss, 2002.

[25] "*A polder is a low-lying tract of land enclosed by embankments (barriers) known as dikes that forms an artificial hydrological entity, meaning it has no connection with outside water other than through manually operated devices*", *http://en.wikipedia.org/wiki/Polder*. These polders prevented flooding of Kopais area, through artificial dams and dykes.

[26] See also Knauss, 2002; Hope-Simpson and Hagel, 2006.

such flood-control works executed in Pheneos, Tiryns, Thisbe and Kopais, one may describe their basic characteristics as follows.

First solution: The waters of the flooding torrent are contained in an artificial lake produced by means of an earth dam, covered by a protective layer of masonry. During summertime, these waters are used for irrigation through a system of small channels; this was the case e.g. of the Arcadian Orchomenos (Pausanias 8.23.2), as well as later on of Mantineia (Thukydides, 5.65). The pertinent dams (containing a clay core) had a height of 3.00 m and they were some hundred or occasionally some thousand meters long.

Fig. 2: Flood control works and land reclamation after drainage of the lake Kopais, during Mycenaean/ Minyan era: remnants of the levees for water routing channels [Photos by the courtesy of professor Th. P. Tassios, (2006, 577)].

Second solution: When such an artificial lake was not sufficient (or perhaps was not feasible at all), another solution was followed. First, the torrent is deviated outside the cultivated lands by means of an appropriate large channel. Secondly, this channel is extended towards the perimeter of the valley, close to the surrounding hills, so that the outflow of water be facilitated through existing cesspits in the karstic lime stones of these hills. The internal high fill forming this channel (to the side of the valley) as a width of 20 to 30 m and is covered by an appropriate masonry, protecting the fill against erosion. In this category of solutions belong the marvelous works of the second drainage system of Kopais, during the 14th and the 13th century BCE. This giant technical achievement merits a more detailed description: (a) By means of a 1km long dam, north to (Boeotian) Orchomenos, the waters of Melas river are collected in an artificial lake (12 km^2). (b) Two kilometers northeast of Orchomenos, the waters of the Boeotian Kephissos are deviated by means of an impressive channel, 25 km long, which conveys these waters along the north bank of the valley – in direct contact with the karstic limestone of the mountain, up to the east end of the valley. This channel has a width of 40.0 m and a depth of 2,50m; it was navigable and served efficiently the transportations between the capital city of Orchomenos and the very fertile agricultural areas of Glas. (c) Geomorphology of the northeast end of the valley of Kopais allows for an area of 20 km^2 to be drained by means of a 3 km long dam and a 5 km long ditch, heading north and meeting the large channel. In the middle of this reclaimed land is located the hill “Glas”, headquarters of the management of this local rich agricultural enterprise. (d) Subsequently, our large channel ends up in a large water-containment area characterized by a local system of cesspits. (e) Yet, it seems that occasionally these cesspits were not sufficient to drain these waters to the sea. Thus, a tunnel was driven (of a cross-section roughly equal to 1.45 × 1.75 m and a 10% longitudinal slope), conveying these waters to Larymna bay, in the Euboea gulf. Incidentally, Kakavoyannis has maintained that the people of Temmikes, specialist miners form Lavrion having immigrated (ca. 1600 BCE) to Boeotia, were employed by the Mycenaeans to maintain cesspits or to drive land-reclamation galleries. (f) Thus, assisted by several other peripheral fills, the reclaimed cultivated land is considerably increased. Its central area (140 km^2 large) is rather dry during summertime, serving only as grazing ground.

This giant-scale land-reclamation system explains the wealth of the “twelve cities of Kopais” mentioned by Homer, and it is another proof of the fundamental *technophilia* of the Achaeans”.

In the same context, it is worth noting another category of flood-control Mycenaeans works to protect the ground of Olympia, where the equestrian Games used to take place. That piece of land was eroded both by the river Alpheios and its tributary Kladeos, near the area of their intersection. The works consisted of two major components: (i) a 500 m long regulatory wall along the east river-bank of Kladeos; the wall containing a core (made of clay and small stones) and masonry covered sides (made of 0.70 m large stones), had a cross-section of 3 × 3 m; and (ii) a large fill along the north river-bank of Alpheios (see also Pausanias, Ηλιακά, 20/15). The area included in the corner of these two protective works, was subsequently infilled, and is still kept intact up to our days (Tassios, 2008).

Knauss (2002)[27] refers also: (1) three basins in Arcadia, in: Tegea an earth- dam, Mantineia an artificial lake, the dam of which was demolished on 418 BC during Peloponesian War, the Land Reclamation works in Orchomenos of Kafyes, the ditch of Hercules in Feneos valley and the "Stymphalian birds"[28], having their nests in the marshes in Stymphalia (there is a dam in the area). (2) in ancient Olympia the deviation of Alpheios river through a dam[29]. (3) in Boeotia, besides Kopais dams in Thisbe, for water-control. (4) in Argolis: the dam in Mycenae, the deviation of the river in Tiryns, through a dam (dated at LHIIIB by Hope-Simpson and Hagel), the drainage of Lerna's marshland a number of "highway"-bridges/sewers. (5) the dam of ravine in Akarnania and (6) in Thessaly: the embankment of the mountain Petra in Voiviis Lake and protection works in the voe of Arni-Kierion. Hope-Simpson and Hagel (2006) date the Ayios Gheorgios bridge and reservoir dam (?) at Mycenae at the LHII or even earlier.

A possible artificial port of LHIII period (radiocarbon dating of 1350 BC) at Pylos is also discussed among the hydraulic works of Mycenaeans[30]. "A Late Bronze Age date for the construction of the port makes perfect sense considering the role of Pylos as the only Mycenaean palatial center on the Ionian side of Peloponese. The kingdom of Pylos had sufficient economic incentive, manpower, know-how and political authority to justify and realize such a project"[31].

Evidence has been clearly cited, in this study, that a cutting-edge technology and an advanced "engineering" know-how existed in Minoans and Mycenaean Greeks since at least the early MH (or even Early-Helladic/ Early-Minoan (EH/EM, ca. 3300-2200/2100 B.C.).

5. Was There a "Flow of Technology" from Ḫatti to Mycenaean Greece or Vice-versa?

In tablet Kbo 3.57, king Hantili boasts that he fortified the cities and Hattuša. Some researchers (Giannakos, In-Press) support that it *was Hanitli I*, 1590-1560 B.C., and speak about a *flow of technology from east* (Ḫatti) *to west* (Mycenaean Greece) since the *postern gates in Boğazköy, date to the 16th century B.C. and the corbelled vaults occur only in the Argolid in LH IIIB*! This aspect adopted already by some archaeologists is against the aforementioned analysis. Mycenean "*Civil Engineers*" disposed *the technology and know-how* and were designing and constructing the *large bee-hive tholos tombs of ashlar-masonry in the corbelling vault technique,* with perfect fitting of the stones (no paper-sheet can intrude in the joints), since late-MH in Peloponese; Minoans since the mid-late-3nd millennium (Hatti's beginning ~1650B.C.). Furthermore: Hantili II (~1450 B.C.) constructed the fortifications (Bryce 2009; 2005, Schuler also; Freu et al., 2010, Onofrio Carruba also; Collins, 2007); the two-dimensional arcs, creating empty space inside the walls' mass, firstly appear, as "*engineer's conception*", in Phylakopi-Melos, at Late-Neolithic or EBA (Tsountas, 1928; Hope-Simpson and Hagel, 2006; Whitelaw, 2005); in Kiapha-Thiti, Phylakopi, Ayia-Irini-Kea and Crete, the fortifications, dated LHI-II (begins ~1620/1580 B.C.), "*contain "sally ports" and ramp*", which could be considered as forerunners of Mycenaean fortifications (Hope-Simpson and Hagel, 2006).

The material evidence for Minoan/Mycenaean Greeks depicts plausibly an opposite "*flow of technology*", *from west to east* (analysis: Giannakos, 2012; In-Press). Over and above, for the Mycenaean frescoes from Hattuša: "*the direction of technological transfer seems to go from west* (Mycenaean Greece) *to east* (Land of Ḫatti) *and the*

[27] See also Hope-Simpson and Hagel, 2006.
[28] Defeated by the hero Heracles (Hercules) in his Sixth Labour for Eurystheus.
[29] Hope-Simpson and Hagel are sceptical about the dating at Mycenaean era, and refer that the nearest Mycenaean settlement at Drouva, opposite to Olympia gave sherds mainly LHIIIB.
[30] Hope-Simpson and Hagel, 2006. A second date of 1010 BC was also measured but it is much later than the Mycenaean era.
[31] According to Zangger et al. as cited in Hope-Simpson and Hagel, 2006.

*limited publicity given to these fragments is the likely reason why these paintings were never considered in relation to Aegean paintings and technological transfer discussion*s" (Brysbaert 2008).

6. Concluding Remarks

The cutting-edge technology and know-how is of decisive importance since, in all eras, both are possessed by the "Great Powers", each-time, and they are combined with excessive wealth and military superiority. Excessive wealth and internal peace are needed for the financing such great scale projects in all sectors of "Civil Engineering". Mycenaeans possessed high-level cutting-edge technology and know-how, for: metal and weapons production, design and construction of very complicated and intuitive structures and building techniques, hydraulic and port works as well as conspicuous wealth in monumental graves, from –at least– the early-16th century B.C., and the Minoans from at least 22nd century B.C., well before the appearance of Hittite empire on the scene of the History (~1650 B.C.). The evidence leads to the direction of a transfer of technology and know-how from west to east and not from east to west.

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