ΑΙΓΑΙΑΚΕΣ ΣΠΟΥΔΕΣ
AEGEAN STUDIES
NO. 1 | 2016 | 57-81
ONLINE PUBLICATION
JANUARY 1, 2016

CALCULATING THE MANPOWER REQUIREMENTS FOR THE CONSTRUCTION OF NEOPALATIAL BUILDINGS IN CRETE: PITFALLS, CHALLENGES AND POSSIBILITIES

REVIEW ARTICLE OF MAUD DEVOLDER, 2013.

Construire en Crète minoenne. Une approche énergétique de l'architecture néopalatiale [Aegaeum 35], Leuven-Liège: Peeters (Hardback, vi & 165 pp., 23 figs., 3 maps, 29.50 x 21 cm, ISBN 978-90-429-3007-0)

VASSO FOTOU

Construction methods and materials have received a fair amount of attention from scholars of Bronze Age Crete. Particularly in recent decades, discussions on materials and techniques are invariably included in publications of individual buildings or settlements.[1] This attention to the subject of materials and techniques in case studies owes a lot to Joseph Shaw's seminal work published in 1973 and re-edited in 2009, which surveys and synthesizes evidence from a wide range of buildings of all periods, from the beginning of EM to the end of LM, representing all major sites on Crete (Shaw 1973; 2009). It was followed by many articles, each focusing on a particular question (a technique or a type of material) by the same author (Shaw 2009: 220-221 for references) and other scholars, including the reviewer.

1 Such as: Knossos (the Central Palace Sanctuary: Panagiotaki 1999: 192-238 *passim*, 242-245, 257-267; the Unexplored Mansion: D. Smyth, in Popham *et al.* 1984: 99-125; the Little Palace: Hatzaki 2005: 65-73; the Royal Villa and the House of the Chancel Screen: Fotou 2013: vol. 2, 62-76, 271-277); Malia (the Quartier Mu: M.E. Schmid, in Poursat *et al.* 1996: 75-99); Kommos (the North House and the House with the Press:

Maud Devolder makes a different contribution to this scholarship with this *Aegaeum* volume which, together with a number of articles published or in print, is the result of her 2003 *mémoire de licences* and her 2009 doctoral dissertation, both submitted to the Université catholique de Louvain (p. iii and Bibliography p. 151). The purpose of the book, as set out in the Introduction (p. 4, 6), is to provide an 'energetic' method by which it is possible to calculate the time necessary for the construction of buildings in Crete during the Neopalatial period (XVIIth-XVth cent. B.C.), with a number of applications on specific buildings from eight sites demonstrating the method and assessing its value.

The method proposed is inspired mainly by scholars on Mayan architecture and particularly by Elliot M. Abrams whose book *How the Maya Built their World* details the energetic quantification of Mayan architecture with several applications on Late Classic Maya residential structures (700-900 A.D.) at Copan, Honduras in Central America.[2] It was in fact this book that gave D. the impetus to undertake this work (p. iii), subsequently becoming also her main source of data. That said, the study of the logistics of ancient buildings is not unknown to scholars of ancient Mediterranean. Janet DeLaine pioneered this approach for Roman architecture with her study of a large-scale building project in imperial Rome, the Baths of Caracalla.[3] This exemplary work, also used by D., albeit occasionally, has been followed up by many scholars on Roman architecture,[4] and there is, to my knowledge, at least one application on Classical Greek architecture, the shipshed complexes at Zea military harbour in the Piraeus.[5]

In the **Introduction** D. gives the outlines of the two parts which compose the book (p. 6, 7-8) and helps the readers to familiarise themselves with the notion of architectural energetics by providing an overview of the energetic method (p. 4-5, 6). In essence, this method involves two main stages: the quantification of the volumes of materials and of the surfaces of a building, and the transformation of these values into labour costs. This transformation is achieved by applying to each component task involved in creating the corresponding volumes and surfaces (*i.e.* acquisition,

M.C. Shaw, in Shaw & Shaw [eds] 1985: 30-31, 109-113; the Oblique House: L.F. Nixon, in Shaw & Shaw [eds] 1985: 63; the House with the Snake Tube: J. McEnroe, in Shaw & Shaw [eds] 1985: 200-202); Gournia (the Palace: Soles 1991: 31-35, 35-70 *passim*); Pseira (various buildings: J.C. McEnroe, in McEnroe *et al.* 2001: 30-78); Palaikastro (Driessen 1984). A significant addition to this list is Akrotiri on Thera. Here the buildings exhibit similar construction techniques with those on Crete, but their conservation allows for a more detailed study of these techniques which was thoroughly conducted by C. Palyvou and presented in exemplary manner in a volume in Greek and in a more condensed version in English (Palyvou 1999; 2005: 111-154).

2 Abrams 1994. For an overview of various applications of the method to Mayan architecture by other scholars, see Abrams 1994: 5-6, 37-41.

3 DeLaine 1997.

4 Barker & Russell 2012: esp. 84 (with references).

5 Pakkanen 2013.

transport and manufacture of the materials and all the different tasks involved in the construction process) standard costs ("coûts standards"[6]). These standard costs are expressed in m^3 or m^2 per unit of labour-time called person-hours or p-h ("heures de travail par personne" abbreviated "h-p").

The heart of the energetic approach and the key element on which the application of this method depends are the standard costs. Fittingly, the first part of the book is devoted to them while the second part presents the application of this method to Neopalatial architecture through a number of case studies.

In this review, I will focus on the calculation of these costs which I believe raises many questions. I will then look more briefly at the case studies focusing in particular on the factors which govern the application of the energetic method on these buildings. There are no quick ways to assess the intricacies of the energetic method in its application on Neopalatial buildings. The following detailed explanations, however necessary, will lead, I am afraid, to a rather long review.

The first part of the book ("The energetic approach: The standard costs") is composed of five sections which detail the calculation of the standard costs involved in each of the five components into which D. has divided the construction of Neopalatial buildings: preparation of the building site; stone masonry; mud brick walls; mortar; and wooden architectural members. There follows a very helpful tabular presentation of these standard costs (p. 42-47).

Section 1 is concerned with the preparation of the ground prior to building. D. focuses on buildings built on slopes and requiring levelling of the ground, which involves either cutting into the slope and building a retaining wall against the cutting or raising the required area with a fill contained by retaining walls, or a combination of the two processes (p. 12). Two standard costs are devised, one for each of the levelling processes. No reference is made to the task (and the ensuing standard cost) of clearing the site of pre-existing structures which would precede any levelling but which may also apply in cases where no levelling is required.

6 Term borrowed from Abrams, equivalent to "labour constants", a more appropriate term perhaps, used by DeLaine (1997).

For levelling by removing soil or rock, D. adopts the standard costs generated from conducting similar work in Tropical Africa and Great Britain. The choice of these standard costs concerns four types of soils which seem to be of similar consistency to those on most Neopalatial settlements. It does not appear, however, to take into account the impact the difference in tools and in local conditions has on the amount of labour required for this particular task—an element that introduces some concern as to the application of these standard costs in a Neopalatial context.

For built-up terraces D. makes use of a standard cost from G. Pegoretti's XIXth century Italian architectural handbook, noting that this is also used by DeLaine (p. 14 n. 23). In fact, however, DeLaine uses this constant in relation to laying foundations in trenches and mixing mortar:[7] this discrepancy makes me question the compatibility of the two tasks and therefore the applicability of this cost to Neopalatial buildings.

Section 2 deals with the stone masonry and it is here that we encounter most of the standard costs. It begins with a survey of the sources of the four main types of stone used in Minoan architecture (limestone, gypsum, sandstone and schist) with a brief reference to other less used stones. The rest of this section is divided into five sub-sections concerning the calculation of the standard costs of the procurement of ashlar and of rubble, of their transport, and of the working and of the uses of stone in Neopalatial architecture.

The procurement of ashlar involves quarrying. D. identifies two different quarrying techniques and devises two standard quarrying costs one for each of the techniques. Reference is made to the density of the different types of stones but neither this nor the other physical properties of the stones which are relevant to quarrying, *i.e.* the consolidation and cement, the texture and the hardness, have been taken into account in determining the standard costs.

The first standard cost applies to sandstone and to the soft limestone-*poros*, both quarried by means of channelling. Notwithstanding the application of the same standard cost to two different stones, the calculation of this cost is based on Italian pre-industrial

7 DeLaine 1997: 175, 176 table 15, 184, 268 with n. 4.

labour constants (it actually represents the mean of two such constants), which involve steel tools and, more importantly, they concern the quarrying of marble (p. 21 and *cf.* table 7 p. 43). D. seems to imply that the combination of marble-steel tools can equate that of soft stones-bronze tools in terms of labour time; I am not sure of the validity of this argument. It needs practical testing.

The second standard cost applies to the soft stone of gypsum and to all hard stones extracted from stratified outcrops by using wedges and levers along the natural lines of breakage. For these stones D. adopts Abrams's standard quarrying cost based on extracting tuff at Copan, presumably following a similar technique but using steel tools (p. 22-23). To measure the total quarrying time in h-p represented by the volume of stone quarried D. uses a formula involving (in addition to the standard cost and the volume of stone quarried), the density of the stone (that of gypsum or of the precise hard stone, p. 23 and tables 7, 8). The question arising here is whether it is right to assume, as the use of this formula seems to imply, that the inclusion in the final calculation of the density of the precise stone compensates for the fact that the standard quarrying cost is based on a very soft ashflow tuff extracted using steel tools.[8]

An additional element in the calculation of the procurement of ashlar is the ratio between the volume of the quarried stone to the volume of the finished blocks. D., based on an estimate waste of 15% suggested by Shaw for trimming sandstone blocs on the building site, considers the volume of all quarried stone to be 115% of the volume of masonry as measured on the structure (p. 23 with n. 110, 32 with n. 180, table 8 p. 45, 46).

However, Shaw's figure of 15% clearly does not correspond to the total waste. As much as 70% of total waste is implied by the "recovery coefficient" for blocks from the Zakros, Mochlos, Palaikastro and Malia sandstone quarries;[9] this is comparable to 75% suggested for marble,[10] but a lot higher than 45% suggested for manufacturing tuff blocks at Copan.[11] Differences in the degree of consolidation of the stone could well account for these variations in the waste, also raising doubts about the validity of applying a common value for waste to all the types of stone.

8 Abrams 1994: 71.

9 Shaw 2009: 32 and n. 158-162 (with references).

10 R.-M. Lambertie cited by DeLaine 1997: 121 with n. 89.

11 Abrams 1994: 45, 46, 71-72, wrongly reported by D. to be more than half, n. 180 p. 32.

Another point here concerns D.'s figure of 115%. The volume of the quarried stone does not equate to 100% of the volume of masonry on the structure with 15% added for the presumed waste, as this figure implies. To extrapolate the volume of the quarried stone from the volume of masonry on the structure, the latter should be divided by the recovery coefficient, *i.e.*, 0.85 for 15% waste;[12] the result is higher than 115% and the difference increases manifolds with the increase in the waste percentage.

Far more common than ashlar, rubble was also naturally more readily available. Assuming that the practice of gathering up rubble does not require any particular techniques or tools, one can reasonably accept D.'s use of Abrams's timed observations of this practice at Copan in determining the standard cost for the procurement of rubble (p. 24). But can one assume this?

Next the question of transport is addressed (p. 24-31) which might have been better placed in a separate section since it concerns (albeit to various degrees) all materials (D. returns briefly to this question in relation only to some pieces of timber, see *infra*). D. reviews the various modes of overland transport before retaining the ox-cart for large and indivisible loads above 200 kg, and the porterage by men or pack animals for small and divisible loads below 200 kg. The quantification of the former is based on a standard load of 2100 kg (just over 2 tonnes). An example is given (p. 27) to show how this standard load allows one to calculate the time in p-h of the ox-cart journeys. It is not clear why the time for loading, unloading and the return time of the cart are not included,[13] but the main issue here is the calculation of the standard load.

D. derived the standard load from an equation linking the weight of a load to the tractive force necessary to pull the load, also involving a coefficient of friction (between the vehicle and the surface of the road) and the inclination of the road which should not exceed 10%; for her calculation of the load (in which D. omits to acknowledge the weight of the cart) D. assumes an ox-cart with a single yoke, and adopts an average coefficient of friction and an inclination of 5%. However, this equation suggests (as it is also clear from its original application by G. Raepsaet and M. Tolley, from where D. borrowed it) that the load should be calculated accord-

12 *Cf.* Abrams 1994: 46.

13 *Cf. e.g.* DeLaine 1997: 128.

ing to the precise transport route, taking into account its specific inclination (thus confirming also whether or not this equation is applicable), as well as its other physical characteristics in order to devise the coefficient of friction and to assess the number of yokes (it is unclear why a single yoke is chosen here over a double yoke). Used correctly, this equation is incompatible with D.'s idea of a standard load which can be applicable to any transport route, especially in the hilly Cretan countryside. For the same reason we cannot rely on the loading limits for a single yoke given in ancient sources.[14] However, it is noteworthy that their values vary, at around a quarter of D.'s standard load of 2100 kg, and even if these are underestimates and the real value was 800 kg,[15] the difference between the two estimates (2100 kg and 800 kg) is still too big even if we account for the weight of the cart. Clearly, the quantification of overland transport of ashlar masonry involves knowing the topography and the location of the quarry as well as the transport route followed to the building site which, apart from anything else, might not be appropriate for an ox-cart.[16]

Overland transport of small or divisible loads used in Neopalatial architecture involves an array of materials, and it is not clear why D. limits her application to earth and to rubble (p. 29). That said, she rightfully posits that these materials existed in the immediate environment of the sites, and that human load-carriers were more appropriate for transporting them to the building site than pack animals. On this basis, D. adopts a formula used by Mayan scholars which measures the output of manual transport in relation to the load (expressed as a volume), the transport distance and the speed of the carrier when loaded and unloaded. The values attributed to the last two variables are not justified by D., but she considers carefully the other two, correctly opting to derive distances as the case arises rather than to adopt a standard distance (equivalent to 250 m) thought to be 'profitable' or 'cost-effective' by Mayan scholars, while the mass of 40 kg suggested as the average load seems reasonable. This means, however, that the application of this formula involves knowing the specific locations of these two materials and also their specific density—the latter being necessary for converting the 40 kg mass into volume.

14 DeLaine 1997: 108, 128-129.

15 Russell 2013: 98.

16 A possibility D. does not consider (p. 26), but see Shaw 2009: 38 with n. 199. See also Panagiotakis *et al.* forthcoming; Russell 2013: 100-101; Shirley 2000: 174-179, 218-219.

Notwithstanding the difficulty in determining the exact locations of these materials, acknowledged by D.,[17] the conversion from mass to volume of the earth and rubble also raises doubts. D. equates 40 kg of earth to a standard volume (0.02 m^3), based on measurements involving the earth used in the construction of the Poverty Point Mount (NE Louisiana, USA), while for the rubble she suggests that the density relevant to each stone should be used.[18] I am not convinced of the universality of the Poverty Point Mount measurement,[19] but I also wonder how feasible is to involve the density in regards to rubble which could represent a variety of stones. It seems to me that sample weighing of the actual materials is the only reliable way forward.[20]

The quantification of maritime and fluvial transport, whether by boat or rafts, presents a whole different set of problems. D. balks at exploring this question, conceding that there are too many unknowns (p. 28). Yet, there are buildings where transport of ashlar and/or timber was almost entirely done over water.[21] The fact that omitting this task presents an unrealistic picture of the quantification of the overall transport, while acknowledged by D., should somehow be reflected on her calculations.[22]

The third task to do with stone masonry is giving the stones their final shaping. Stone-cutting, D. argues (p. 31-32), took place entirely at the building site. She considers the two techniques involved, indirect percussion (mainly chiselling) and sawing, and their uses in relation to shapes and types of stones cut. Following these distinctions she devises three standard costs to which a fourth is added for roughing-out stones.

The first standard cost, for chiselling blocks of sandstone, soft limestone-*poros* and probably also gypsum, corresponds to the standard cost devised by Abrams for cutting tuff bocks by indirect percussion using steel tools. The second, for sawing slabs and other shapes (including blocks) of gypsum, corresponds to the constant given in Pegoretti's XIXth century handbook for sawing Carrara marble. The third, for sawing hard stones, is based on the results of a large-scale experimental sawing by D.A. Stocks of a block of rose granite in Aswan (Egypt) using a flat-edged, stone-weighted copper saw. The fourth, for roughing-out stones, is based on Abrams's

17 P. 31, but see p. 20, 30, where this task is deemed "impossible".

18 P. 31, but note on table 7 p. 43, the volume given for the earth is presented as the average value for (any) divisible load.

19 *Cf.* Abrams 1994: 48 where he equates 0.02 m^3 of earth to 22 kg, based on experiments at Copan.

20 *Cf.* Abrams 1994: 46-47, 48.

21 See Shaw 2009: 37, for the buildings at Pseira, or Fotou 2013: vol. 2, 63-64, for the Royal Villa at Knossos.

22 Some information could perhaps be extrapolated from Russell 2013: 95-96, 105-140.

estimation that this should represent 10% of his cost for cutting tuff blocks used by D. for chiselling.[23]

The logic of adopting standard costs devised for different stones cut with steel tools, which underpins D.'s first two standard costs, has been already questioned in relation to quarrying. The validity of the standard cost based on Stocks' experiment cannot be doubted, but I wonder why D. did not consider Stocks' adjustment of the rate achieved through his experiment to the ancient rate, assumed to be double.[24] That said, other small-scale experiments by the same scholar point against applying the figure for rose granite indiscriminately to any hard stone: copper saw cutting rates for hard limestone (Mohs 5) and calcite (Mohs 3-4) were shown to be 9 and 18 times respectively faster than the rates for granite.[25] This highlights the problem of applying one standard cost for cutting to stones of different physical properties, particularly in hardness and texture,[26] as in the case of D.'s first as well as second standard cost: the texture of gypsum used in Neopalatial buildings varies too much to assume cutting rates in the same order of magnitude.

Another issue here is the applicability of the first two standard costs particularly in relation to blocks. Soft sandstone, soft limestone-*poros* and gypsum (Mohs 3 and below), which often account for the majority of ashlar blocks, can be cut with any copper or bronze edged tool, chisels, adzes and double axes as well as saws, serrated or flat-edged ones.[27] Although detailed observations of the tool marks left on a number of ashlar wall blocks of these three types of stone affirm the importance of chiselling in cutting such blocks,[28] sawing, as D. points out (p. 32 with n. 186) was also used. This raises the question which of the first two standard costs suggested by D. should be applied in cases where no tool marks are visible.

Finally, the question of building with stone is addressed (p. 34-35). D. distinguishes two types of stone wall construction, ashlar and rubble, and devises one standard cost for each type. The first corresponds to Abrams's standard cost based on timing the reconstruction with tuff blocs of the lower parts of walls 0.25 m thick of a number of ancient buildings at Copan. The second corresponds to Rea's early XXth century British architectural textbook standard cost for building rubble walls.

23 By mistake the figure 0.162 m^3/p-h D. gives for this cost (p. 34, table 7 p. 43) represents 1000% of the cost for chiselling which is 0.0162 m^3/p-h (p. 32, table 7 p. 43); the correct figure is 0.00162 m^3/p-h.

24 Stocks 2001: 94.

25 Stocks 2003: 115 table 4.2, 117 table 4.4.

26 *Cf.* Barker & Russell 2012: 86, 89.

27 Stocks 2003: 64, 65, 67, 69. See also Lowe Fri 2011: 58-60, 65.

28 Shaw 2009: 46-47.

The processes behind these standard costs are not explained in order to say whether extrapolating construction costs for the Neopalatial period from these sources is justified. Nevertheless, the relative thinness of Abrams's walls (their width is 0.25 m), compared to that of Neopalatial ashlar walls, already suggests a fundamentally different construction. Another point which can be made is that Abrams's cost is not representative of the construction of the whole wall but refers only to its lower part, thus omitting the cost for lifting materials. This flaw, acknowledged but ignored by Abrams,[29] could hardly be passed over in the quantification of Minoan wall construction which concerns much bigger blocks than those used in the walls at Copan (given their width of 0.25 m) and probably higher walls.[30]

Section 3 is concerned with the sun-dried mud brick walls. It begins with an overview of the uses of mud bricks in wall construction, their composition and their physical characteristics. The rest of the section is divided into three sub-sections dealing with the standard costs of each of the three tasks involved in the use of mud bricks in walls of Neopalatial buildings: procurement of materials, manufacture and construction. Transport is not mentioned here but the cost of earth transport is included in table 8.[31] The questions raised by the calculation of this cost have been already discussed in relation to transport of small or divisible loads under Section 2. The use of this cost for bricks implies that brick-making is assumed by D. to be taking place at the building site. Given, however, the space requirements for manufacturing and drying mud bricks, it is more likely that, at least in towns, this activity was taking place at specific installations as Shaw has suggested,[32] situated probably near a water supply and close to the supply of earth.[33] This would alleviate D.'s transport costs for the main raw materials but there should be instead transport costs for the finished bricks from centre of production to building site.

Procurement requirements for water and binding materials are considered by D. following Abrams to be negligible, although to me this seems debatable. That leaves the main materials, earth and sand, for the procurement of which D. applies the standard cost devised for levelling by cutting into sandy earth, a task dis-

29 Abrams 1994: 51.

30 Evely 1993: 217; see also DeLaine 1997: 178 with n. 6.

31 P. 47: "Murs de briques", *cf.* table 7 p. 43 and p. 31 for the value of "Q".

32 Shaw 2009: 127.

33 Fathy 1989 [1969]: 91, 198-199.

cussed under Section 1. The figure given here (p. 36) and on table 7 p. 43 (0.1 m^3/p-h) does not correspond to any of the values listed under levelling (p. 13 with table 2); a different figure (0.8 m^3/p-h) is given on table 8 (p. 47: "Approvisionnement") for which I could not find an explanation as to how it was derived. This apart, one potential flaw in this cost is that sandy earth may not be available on all sites and procurement of sand may be required.[34]

For making mud bricks, D. devises two standard costs, one for mixing the materials and one for moulding into shape. The first corresponds to the constant given in Pegoretti's XIXth century handbook for fired bricks, used by DeLaine (p. 37 n. 231); the second is deduced from Fathy's figures based on making mud bricks for building houses at Gourna, Egypt, using traditional methods.

Judging from DeLaine's description, the process involved in the production of fired bricks differs from that of the sun-dried bricks.[35] This difference seems to impact considerably on the time for mixing the materials since the figure one can deduce from Fathy's data (specifically based, as noted above, on making mud bricks using traditional methods) is 6.5 times higher than Pegoretti's.

More specifically, Fathy informs us that the mixture corresponding to 3000 mud bricks of 0.23 x 0.11 x 0.07 m, took one person one day's work to prepare;[36] given that this mixture was poured into moulds measuring 0.24 x 0.12 x 0.08 m,[37] its volume was at least 6.91 m^3.[38] Assuming (as D. suggests, p. 37) that Fathy's average working day was 8 hours, this mixture gives a preparation rate of 0.86 m^3/p-h against Pegoretti's 0.1315 m^3/p-h. The choice of Pegoretti's figure for this task over the clearly more reliable Fathy's data is even more puzzling since D. uses the latter to calculate the standard cost of the next as well as of all other similar tasks.

Indeed, the validity of D.'s second standard cost (for moulding the mixture into shape) deduced from Fathy's figures, cannot be doubted. However, the difference between the size of Fathy's bricks and the range of sizes of Minoan bricks recorded by Shaw,[39] is considerable and an adjustment of this standard cost is necessary.[40] Moreover, it is not clear why D. did not include in the standard cost the task of setting the bricks on edge which is a well documented part of the process of drying. The fact that it helps to achieve even

34 Fathy 1989 [1969]: 147, 224.

35 DeLaine 1997: 114 and n. 54.

36 Fathy 1989 [1969]: 200.

37 Fathy 1989 [1969]: 198.

38 The difference between brick size and mould size, suggests a shrinkage of about 23% of the bricks after drying overlooked by D., *cf.* n. 233 p. 37, where the original mixture is considered to be equal to the volume of the 3000 finished mud bricks.

39 Shaw 2009: 132, 183-188.

40 *Cf.* DeLaine 1997: 116, 118 table 9.

drying and to prevent bending and cracking must have been realized by the Minoans.[41]

This point raises also the question of wastage. Wastage in mud brick construction—whether during production, transport (if we accept that the production took place at a specific site away from the building site as suggested above) or use—has escaped attention by D. It is, however, a question which deserves consideration even though, at first glance, the quantification of this particular wastage seems to lack evidence.

For the construction cost D. uses the mean of Fathy's two standard costs for building mud brick walls at ground floor level below and above 1.20 m. Given D.'s argument that brick was mostly used for upper floor walls (p. 35) I wonder why she did not chose to use Fathy's figure for first floor walls which includes the labour for transporting the materials.[42] As stated above Fathy's brick size is much smaller than Minoan brick sizes and some adjustment of this standard cost should also be made.

In the short section that follows (Section 4) concerning the mortar (p. 38) D. focuses only on the mortar used in wall masonry to bind together the stones or the mud bricks. She returns briefly to this material in relation to ceiling and roof construction (see Section 5), but no reference is made to other uses of mortar, even those, such as backing for wall revetments of lime plaster and slabs, and for floor construction at ground level,[43] where the quantities of materials involved and the rendering are not as negligible as to be ignored.

Earth is the only material considered in relation to mortar used in wall masonry. The standard costs for procurement and for transport of earth discussed above in relation to mud bricks also apply to mortar. For the remaining standard cost of mixing the mortar, given the reliability of the task described by Fathy, one can reasonably accept D.'s use of Fathy's data in determining this cost.[44]

The application of these standard costs is linked to the quantities of mortar used in the various types of wall construction. D. calculated the percentages of mortar for each of the three types of stone masonry identified (rubble, ashlar, roughed-out blocks) and for mud brick walls.[45] The percentage of mortar in ashlar walls considered by D. as negligible refers in fact only to

41 Fathy 1989 [1969]: 90, 200; Wulff 1966: 110, 116.

42 Fathy 1989 [1969]: 208.

43 Shaw 2009: 127, 141.

44 It should be noted, however, that the figure on which this standard cost is based is 0.20 m^3/p-h in Fathy 1989 [1969]: 206, instead of 0.23 m^3/p-h noted by D. (p. 38) but which is based on a French version published in 1970 (n. 243 p. 38).

45 The latter is noted as 25% in the text (p. 38) but 30% on tables 6 (p. 38) and 8 (p. 47).

the ashlar face of the wall, the other face, made of rubble and mortar, being considered separately as the case arises (*cf.* table 8 p. 45). Given that all other percentages are clearly averaged estimates only, I do not see the reason why D. opted for this solution in the case of ashlar walls which requires complicated calculations and is unlikely to provide a more accurate figure than an average percentage which she could obtain by measuring representative examples of ashlar walls.

The final section, Section 5, looks at the wooden architectural members. It begins with a brief overview of the species of constructional timber identified in Minoan Crete and the uses of timber in walls, columns and ceilings supporting either the floor of an upper story or a flat roof (p. 39-40). The rest of the section is divided into three sub-sections dealing with the standard costs of felling trees, of timber manufacture and of the use of timber in the construction of ceilings and columns with a brief reference to the costs of transport and of related materials. The claim (p. 40, 41) that the use of timber in wall masonry is not evident enough to allow quantification is puzzling given the wealth of evidence already summarized by D. (p. 39) and discussed at length in the bibliography.[46] The elimination from quantification of this and of other equally well documented common, as much as wide, uses of timber, as in the construction of staircases, doors and windows,[47] is of importance here since these uses contribute significantly to timber and labour requirements.

D.'s standard costs of felling trees (p. 40) and of timber manufacture (p. 40-41) correspond to the time (in minutes per person) used to fell and process respectively 1 cm^2 of any tree trunk.

The estimation of felling time is based on the felling times of three oaks of 15, 30 and 60 cm diameter cut with a stone adze or axe generated by Startin for his quantification of the labour expended in the construction of a tripartite house of mid-fifth millennium B.C. in Europe (p. 40). These rates represent subjective, albeit informed, estimates Startin was forced to make "in the absence of more conclusive data".[48] Their validity seems to be challenged by Shirley's estimation of the felling time of oaks of 20 cm diameter assumed to have been used in

46 See in particular Shaw 2009: 96-102, 114-120; Tsakanika-Theohari 2009.

47 Shaw 2009: 102-104, 110-125 *passim*.

48 Startin 1978: 154.

the construction of the Roman Legionary Fortress at Inchtuthil:[49] this time, although it assumes the use of a steel axe instead of a stone one, is 25% longer than Startin's felling time of an oak of the same diameter but, correctly so, it includes the time for clearing the terrain prior to felling.

That said, the main issue here (as with stone-cutting) is whether D. is right to apply Startin's felling times of oak (a dense hardwood) achieved with stone adzes to felling, using, as the Minoans did, bronze axes,[50] cypresses, firs and pines, all softwood species representing the main constructional timbers in Minoan Crete.[51] The use of bronze axes instead of stone adzes clearly affects the felling time, although no precise ratio has been established.[52] With regards to felling times of different species, some indication is given by the discussion of the 1st century A.D. Roman writer Columella on the squaring or sawing of timbers, which allows to compare the amounts of pine, cypress and fir timbers that a man can square or saw in a day to the amount of oak: these being a quarter, twice and three times respectively larger than the latter.[53] Further indications can be gleaned from Lowe Fri's experiments of felling three species of trees of different hardness using replicas of Minoan double axes.[54]

These observations are also valid for the 'manufacture' time, since the estimate for the latter, devised by Sehested and used by Startin from where D. borrowed it (p. 40 with n. 255), is based on the felling time—equalling three times that. That said, the tasks D. attributes to this estimate exceed those referred to by Sehested. According to Startin's use of Sehested's estimate,[55] these tasks relate only to primary handling of the felled trees, *i.e.*, snedding (trimming off branches from felled trees) and debarking, and not to converting them to beams as suggested by D. (p. 40, 41). Converting the snedded trees to beams of a given length involves at least one cross-cut taking the equivalent of the felling time.[56] Neither this nor squaring, for which it is difficult to give a general estimate as it depends on the required shape,[57] is included in Sehested's time, nor therefore in D.'s 'manufacture' time, the latter being limited to primary handling of the entire felled tree.

49 Shirley 2000: 165.

50 Evely 1993: 51; Evely 2000: 530.

51 Meiggs 1982: 100-101; Shaw 2009: 94.

52 Evely 2000: 528; a time ratio of stone adze to steel axe for the same task of about 4:1 or 3:1 is suggested by Cranstone but the type of timber is not mentioned (Cranstone 1971: 133).

53 Passage cited and discussed in Meiggs 1982: 368-369, 516-517 n. 145.

54 Lowe Fri 2011: 55-58, 65.

55 Startin 1978: 154.

56 Startin 1978: 154.

57 Shirley 2000: 166-167.

Construction standard costs suggested by D. consist mainly of applying the two basic costs of felling and of primary handling (corresponding to 1 cm^2 of a tree trunk) to small poles, joists and girders, used in the construction of ceilings, as well as to the column-shafts. D. assumes an average diameter of the tree of 7 cm, 12 cm, 18 cm and 40 cm for each of the four classes respectively (p. 41). The first application gives the felling time (in p-h) for each of these four timber sizes; for the small poles, which form a layer over the joists, D. also devises the felling time per m^2 by assuming a standard length of 50 cm. The second application, taking into account the clarification above, gives the primary handling time (in p-h) for the three main timbers (and not the manufacture time for each of the extremities of these timbers as indicated by D.).

Clearly, two main estimates are missing from the construction costs calculated by D.: the first for converting the trees as well as the branches into lengths, since the latter are assumed to provide poles of a uniform length; the second for joint-cutting (cutting notches, tenons and mortises), moving them into position and fixing the timbers and the poles.[58]

For the calculation of the transport cost D. uses the 'profitable/cost-effective' distance of 250 m between the source of timber and the building site, suggested by Mayan scholars.[59] For most Neopalatial sites, this distance may be a realistic estimate for earth and rubble sources, but *may* is the word: this certainly does not apply to timber.[60] Another point to make is that the overall time allotted to timber transport is limited to the time for transporting the larger timbers (girders and the column-shafts) over the 250 m distance (*i.e.* 9 minutes per timber); the time for loading, unloading, and returning to the source is not taken into account, while the transport cost of joists and poles is eliminated claiming, rather arbitrarily, that it is negligible.

Two other costs are devised by D. for the laying down of clay mortar and slabs over the poles, to form the floor of the upper story and/or of the flat roof (p. 42); they represent overall costs (in h-p per m^3 and m^2 resp.) combining production and transport costs for mortar and stone (p. 42), and are already

58 *Cf.* Shirley 2000: 98-99. At Akrotiri reeds, which act as an alternative to poles also in Minoan Crete (Shaw 2009: 152-153), were hold together with strings (Palyvou 2005: 127 fig. 181).

59 P. 42 with n. 261, and above Section 2, *re* transport of small or divisible loads.

60 *Cf.* Shaw 2009: 37.

discussed above. No standard cost is devised for lime plaster, often used as floor revetment.[61]

To sum up, this examination here of D.'s standard costs casts serious doubt on the reliability of most of them. There are more problems in deriving these costs than are recognised or admitted by the author, and they stem from the sources used none of which relate directly to the Neopalatial architecture or even to Crete in general. Contrary to D.'s assertion (p. 6-7, 11, 141), the inferred link between the production of building materials and the process of construction in Neopalatial Crete and those of the Mayans or those referred to in pre-industrial manuals, which underpins most of the standard costs, proved to be very tenuous. There are significant differences in the raw materials, particularly the stone and the timber, as well as in the tools which compromise the compatibility of the tasks and hence the validity of extrapolating Neopalatial standard costs from these sources.[62] Indicatively, almost all the costs Abrams used for his quantification of structures at Copan were generated on the site itself using the same raw materials and the same tools as those used by the ancient builders, a work he considered of vital importance for a reliable quantification.[63]

Arbitrary assumptions determine the calculation of some costs or the elimination of others (the fact that transport costs are involved in both cases is significant since these costs represent a large proportion of the total cost). Understandably there are tasks that are left out for lack of evidence or because it was too difficult to make realistic estimations (*e.g.* destruction or dismantling of previous constructions; use of timber in windows and staircases), but such claims are not always justified (*e.g.* in the production and use of lime plaster; the use of timber in wall construction and in doors; raising large blocks in wall masonry and converting timber to beams). I also wonder whether the decision to establish costs that are applicable to all Neopalatial sites regardless of the specific environmental advantages and constraints is tenable. All this increases my unease about the application of these costs to specific Neopalatial buildings in the second part of the book.

61 Shaw 2009: 141, 144-150 *passim*, 152. Note that lime plaster is wrongly referred to here (p. 42) and elsewhere in the book as "plâtre" (= calcined gypsum) instead of "chaux" or "enduit de chaux" (= lime / lime plaster): in Minoan architecture "enduit" (= plaster or coating) can be either mud/clay plaster or lime plaster (Shaw 2009: 141) and the persistent use by D. of "plâtre" or "plâtré" is misleading (Aurenche 1977: *s.v.* plâtré).

62 *Cf.* Barker & Russell 2012: 85, 86; DeLaine 1997: 104-105.

63 Abrams 1994: 16, 39-40, 41-43.

The second part of the book ("Case study: The Neopalatial architecture in Crete"), preceded by a concise introduction, presents the evidence for energetic application on a sample of 23 Neopalatial buildings from eight different sites: Klimataria-Manares (homonymous building); Achladia (building A); Gournia (Palace); Mochlos coast (buildings A and B); Mochlos islet (building C3); Chalinomouri (homonymous farmhouse); Pseira (buildings AA, AB, AP, AM, AD North, AD Center, AC, BS/BV, BC, BY; the Plateia or zone BR is also included here, p. 97, although it offers no evidence for energetic application); Knossos (South House, House of the Chancel Screen, South-East House, House of the Frescoes, Royal Villa and Unexplored Mansion). There follows a chapter discussing and interpreting the results obtained from the case studies. A final conclusion brings out the main problems in assessing the energy represented by the various Neopalatial buildings and recapitulates the main interpretations drawn from the case studies.

The case studies are clearly organized and thoroughly researched with detailed references. Dating and phasing of the buildings are discussed as well as the organisation of the extant plan which benefits from illustrations of very good quality. In some cases, there are brief references to the upper floor(s). There follow tables with the results of the quantification concerning the time (in p-h) needed to complete each of the component tasks for the erection of the basic structure—the levelling, wall masonry and ceiling/roof construction, (p. 8, 141)—for which standard costs have been calculated in the first part of the book; costs are presented separately for different architectural phases (if there are any), and the overall time is also calculated. These figures are then assessed with the help of diagrams and graphs clearly set out and beautifully reproduced.

Readers hoping to find in these studies a comprehensive discussion of the issues raised by the standard costs and which are site or building specific will be disappointed; such issues concern particularly the levelling and the supply of materials (location of source, ease of procurement, routes of transport to the building site), and in some cases also the production of materials (shaping) and the specific techniques used in their assembling into the actual construction.

Equally, very little attention is paid to the reconstitution of the original structure of the buildings discussed. D. balks at investigating further the reconstitutions proposed in the bibliography or at exploring this question for the buildings for which such information is lacking. Quantification of the structure in its original form concerns 17 out of the 23 buildings, but only for seven of them are the reconstitutions the result of studies accompanied by drawings: the building A at Achladia, the Palace at Gournia, the buildings A and B on the Mochlos coast, the building at Chalinomouri, and the House of the Frescoes[64] and the Royal Villa at Knossos. Consequently, comparisons of costs between the buildings become tenuous. Also percentages of partial costs (*i.e.* the time needed to complete one task, *e.g.* rubble wall construction) to the overall cost of a building can be misleading particularly in the case of buildings for which the original structure remains largely undefined. Establishing the three-dimensional shape of the building, the nature and quantities of the materials and the type of the tasks involved in the construction of the preserved parts and developing the arguments for determining the fabric of the reconstituted part of the structure, the materials that might have been used and how it could have been built, are fundamental requirements to an energetic approach. General views, such as the use of mud bricks in the construction of upper floor walls, should be reassessed based on building specific data rather than taken for granted: for example, the preserved parts of the upper floor walls of the Royal Villa at Knossos do not present any evidence for use of mud bricks, suggesting that these walls were more probably of rubble rather than of mud bricks as D. assumes (p. 111, 114) based on the general view.

In light of these observations, it is clear that the reliability of D.'s quantification of the labour expended for erecting the basic structure of the 23 Neopalatial buildings is seriously compromised. A few further issues seem to add to this. The first concerns the question of savings from reuse of materials. It is true

64 Following M. Cameron (p. 108 with n. 459), *contra* M. Shaw in Chapin & Shaw 2006: esp. 60, 61, 64, 65, 87-88, and more recently Fotou 2013: vol. 1, 112.

that apart from reused ashlar blocks which are usually evident and quantifiable, it is not easy to tell what has actually been reused in the Neopalatial buildings of sites with a history of occupation. However, Neopalatial buildings erected after razing to the ground existing buildings surely must have incorporated some amount of the fabric and materials of the latter and this should somehow be reflected in the quantifications.[65] Examples of Protopalatial elements incorporated in the Second Palace at Malia have been recently discussed by Shaw.[66] Amongst the buildings discussed by D., one such instance is undoubtedly the rubble used in the construction of the House of the Chancel Screen and the South-East House at Knossos since the erection of these two buildings was part of a big project involving the levelling of the buildings of the entire quarter SE of the Palace; in addition, walls of the razed buildings were incorporated in the platform on which rose the House of the Chancel Screen, and some of these walls also served as foundations for the walls of the latter.[67] In view of this, D.'s figures of levelling and foundations are somehow misleading (p. 105).

Another issue that deserved consideration is the question of remodelling. While D. identifies different architectural phases in some buildings (*e.g.* the Palace at Gournia or the building C3 at Mochlos), she does not investigate further how the remodelling interfered with the existing structure, what was likely or practicable to have been left as such.

Finally, I wonder whether the high cost of brick walls compared to that of rubble walls, repeatedly stressed by D. (p. 59, 67…), could have been influenced by the problems stemming from the calculation of the standard costs discussed above.

We now come to D.'s ultimate goal which is to determine the size of the workforce and to assess the part played in the project by the prospective inhabitants in an attempt to shed light on the energetic impact of the architectural choices and to explore the social and economic ramifications stemming from these choices. Yet again, the parameters involved in the pursuit of this double goal are not convincing.

65 *Cf.* Abrams 1994: 54-55; also Abrams 1998: 137, where the author concludes that evidence of reuse "can result in a 40+% reduction in subsequent expenditures for the largest of masonry structures" at Copan.

66 Shaw 2015: 52-58.

67 Fotou 2013: vol. 1, 79-82, 83, 89; vol. 2, 242-244, 245, 271, 273-274.

To make the leap from the manpower requirements (calculated in p-h) in erecting the basic structure of a Neopalatial building to the actual workforce and determine the total number of people involved in this project, D. assumes for each structure a building period of 90 days with 8 hours as the average length of each working day, a total of 720 hours. By assuming that the total amount of man-hours required for *any given structure* was typically spread over 720 hours, D. determines the number of people involved.

The arguments for the choice of these figures are presented in the Introduction preceding the case studies (p. 50, my translation): "The average length of building season is based on ethnographic data. Many studies suggest that architectural projects were usually carried out over a short period, in order to get the walls roofed over quickly, because otherwise they would have been destroyed by the elements if the building work were prolonged. Similarly, they often highlight the months during which very little work or none at all was required in the fields [footnote 12, with quote from Schloen 2001: 102]. The dry season is therefore generally referred to as the favourable moment for carrying out architectural projects. Many references dealing with Central America, Ancient Greece and West Africa suggest periods between two and five months of work [footnote 13, with relevant quotes, see my comment below]. They concern societies where architecture is almost exclusively the work of non-specialists, and where therefore the workforce has also to go about their main occupations, essentially agricultural, as was the case in the ancient Mediterranean [footnote 14, with bibliographical references]. If some structures, built by their own inhabitants, took only a few months of work, others could, on the contrary, have been the result of a program carried out over a long period because their workforce, freed from the need to secure their own material necessities, was widely available. A building season with a duration of three months or 90 days will be used as a parameter to interpret the costs. In addition, although we stressed in the Introduction of this book the variable length of the working day, an average of eight hours will be assumed in these estimates."

Neither Copan in Central America nor Togo and Benin in West Africa (n. 13 p. 50) provide valid arguments supporting a 90 days construction period in Minoan Crete. The tropical climatological conditions have a determining effect in the length of the building season in these countries, but there are no such constraints in Crete. As for the 4th century record from Eleusis referred to by D., I am puzzled as to how the information that "heavy transport from the quarries, in one instance at least, was done during July and August" relates to the problem of the length of the building season in Neopalatial Crete; in any case, the production and supply of ashlar (and other materials requiring work outside the building site, *e.g.* mud bricks, lime) probably followed a different schedule from that of construction.[68] Construction in Neopalatial Crete could effectively have taken place all year round, and if festivals or adverse weather conditions affected the building period, this could not have been to the extent of limiting it to 90 days. In this respect, DeLaine's discussion[69] of the average working year on the construction site in Severan Rome (end of 2nd-beginning of 3rd century A.D.), assumed to consist of 9 months totalling 220 days, and of the average working day, assumed to be 12 hours with 2 hours for breaks, is instructive. Given the similarity in the climate, these figures represent a more realistic assumption for Crete than those extrapolated from Central America or West Africa.[70]

That said, these figures assume a building period totalling 2200 hours (220 days x 10 hours per day), 3 times D.'s building season of 720 hours. The total costs D. obtained from the application of the energetic method to the 23 Neopalatial structures are relatively low; spreading them over a building period of 2200 hours would reduce the workforce to levels that are neither realistic nor meaningful.[71] Of course, this does not question the length of the building period suggested by DeLaine and whether it is applicable to Crete. It simply shows that the building period is not a pertinent criterion for determining the time taken for erecting the structure of these Neopalatial buildings. Clearly, there are no

68 *Cf.* DeLaine 1997: 106, 189.

69 DeLaine 1997: 105-106.

70 *Cf.* Fathy 1989 [1969]: 153, where he considers the building period in Upper Egypt to be 10 months, July and August being excluded due to temperature rising to 45° C in the shade and 80° C in the sun.

71 *Cf.* graph 23 p. 131 showing the number of individuals involved in the construction of each of the buildings assuming a building period of 180 days totalling 1440 hours.

means of knowing this time and therefore of making a reasonable assumption on the size of the workforce.

This of course compromises D.'s other goal, to assess the part played by the prospective inhabitants in erecting the basic structure of a Neopalatial building, more precisely their contribution to the workforce involved in the construction of the building assumed to be their future dwelling. Nevertheless, her approach in considering this question should be examined. D. estimates first the number of prospective inhabitants, using R. Naroll's ratio of 1 person per 10 m^2.[72] She then follows Abrams in his hypothesis that 20% to 33% of the inhabitants would take part in the construction of their own dwelling, to determine the number of prospective inhabitants included in the workforce determined as discussed above.

I do not believe these estimates have a universal value. If they are to be used in the context of Neopalatial Crete, they should be supported by specific evidence drawn from this context. References to works on Minoan Crete objecting to or doubting Naroll's ratio are diligently listed by D.,[73] but the arguments are not discussed and she makes no counter arguments in favour of this ratio. Notwithstanding the arbitrary nature of this parameter, the main issue here is whether the prospective inhabitants of the Neopalatial buildings did actually contribute to the workforce.

That part of the labour in any given project, particularly that of a house, could have been provided by the prospective inhabitants is possible, but no evidence allows us to suggest, as D. does following Abrams, that this was a permanent feature of the workforce in Neopalatial Crete. It is an arbitrary assumption which D. uses in connection with the calculation of the total number of workers (equally arbitrary, as we argued above) to make further assumptions on the nature of the workforce involved in elite buildings[74] and in vernacular buildings.[75] In view of these major flaws in determining the size of the workforce and the contribution of the inhabitants to it, I do not intend to discuss any further D.'s arguments on the social and economic implications of these two parameters in the construction of the Neopalatial buildings.

72 P. 49 with n. 2: the reference, p. 157, is *American Antiquity*, not *American Anthropology.*

73 P. 49-50 with n. 3-8; we could add here Wallace-Hadrill's discussion of the question of ratio of space per person and in general of population density (Wallace-Hadrill 1994: 92-103).

74 Such as the South House, the South-East House, the Royal Villa and the Unexplored Mansion at Knossos, p. 103, 107, 112, 114, 120, 142.

75 Such as the buildings A, B at Mochlos, the farmhouse at Chalinomouri, and the buildings AA, AB, AP, AD North, AC, BS/BV, BC, BY at Pseira: p. 72-73, 75, 79, 81, 83, 84, 87, 91, 94, 96, 98 resp.; *cf.* p. 119-120 (with a slightly different list), 141-142.

This monograph represents a brave attempt by D. to introduce the energetic approach to Aegean scholarship. However, the data necessary to support this attempt, whether it is to determine the standard costs or the original form of the Neopalatial buildings, are clearly inadequate. There is no doubt that even in calculating the quantities of materials (let alone their transport and use in the construction) simplifications and assumptions are inevitable. However, the flaws in determining the standard costs and the lack of comprehensive studies establishing not only the existence and extent of the upper floors but also how they were built make this process more guesswork than an analysis with reasonable numbers of uncertainties and reservations.

More reliable and site-specific standard costs from new sources (*e.g.* Cretan Venetian or Ottoman contracts or other accounts, or experiments using replicas of Minoan tools) and a more detailed knowledge of the original form and fabric of Neopalatial buildings could effectively allow us to move with some certainty from the quantities of materials to the number of man-hours required for their construction. On the contrary, there is no way to make a reliable estimate of the time over which the number of man-hours calculated for erecting a given Neopalatial structure were spread; thus we cannot hope to move beyond the total cost of the building process to consider the workforce and estimate its size, let alone its nature.

Given these limitations, the question is whether the quest for the kind of data necessary for the application of the energetic approach to Neopalatial buildings would indeed be profitable; I am not persuaded that it would. Instead, two profitable approaches would be comprehensive case-studies of the building process, including the supply of materials, their transport and the techniques used in the construction, or studies of a specific task through a series of buildings. Such approaches would take us further towards establishing the repertoire of construction skills of the Neopalatial builders and understanding their choices.

REFERENCES

Abrams, E.M. 1994. *How the Maya Built Their World. Energetics and Ancient Architecture*, University of Texas Press, Austin.

Abrams, E.M. 1998. 'Structures as Sites: The Construction Process and Maya Architecture', in S.D. Houston (ed.), *Function and Meaning in Classic Maya Architecture*, Dumbarton Oaks, Washington, D.C.: 123-140.

Aurenche, O. (ed.) 1977. *Dictionnaire illustré mutlilingue de l'architecture du Proche Orient ancien,* (Coll. Maison de l'Orient Méditerranéen Ancien 3, Série Archéologique, 2), Lyon.

Barker, S. & B. Russell 2012. 'Labour figures for Roman stone-working: pitfalls and potential', in S. Camporeale, H. Dessales & A. Pizzo (eds), *Arqueología de la Construcción III. Los procesos constructivos en el mundo romano: la economía de las obras* (Anejos de Archivo Español de Arqueologa 64), Madrid & Merida: 83-94.

Chapin, A.P. & M.C. Shaw 2006. 'The Frescoes from the House of the Frescoes at Knossos : a Reconsideration of their Architectural Context and a new Reconstruction of the Crocus Panel', *BSA* 101: 57-88.

Cranstone, B.A.L. 1971. 'The Tifalmin: a 'Neolithic' people in New Guinea', *World Archaeology* 3.2: 132-142. [online]

DeLaine, J. 1997. *The Baths of Caracalla. A study in the design, construction, and economics of large-scale building projects in imperial Rome* (Journal of Roman Archaeology Suppl. 25), Portsmouth, Rhode Island.

Driessen, J. 1984. 'II. Notes on Building Materials and Quarries', in J.A. MacGillivray, L.H. Sackett, D. Smyth, J. Driessen, D.G. Lyness, B.A. Hobbs & A.A.D. Peatfield, 'An Archaeological Survey of the Roussolakkos Area at Palaikastro', *BSA* 79: 143-149.

Evely, R.D.G. 1993. *Minoan Crafts: Tools and Techniques. An Introduction,* Volume 1 (SIMA 92:1), Paul Åströms Förlag, Göteborg.

Evely, R.D.G. 2000. *Minoan Crafts: Tools and Techniques. An Introduction,* Volume 2 (SIMA 92:2), Paul Åströms Förlag, Jonsered.

Fathy, H. 1989 [1969]. *Gourna: A Tale of Two Villages* (Prism Art Series 4), Foreign Cultural Information Dept., Ministry of Culture, Cairo.

Fotou, V. 2013. *Architecture néopalatiale en Crète. Les bâtiments en dehors des Palais et leurs fonctions*, 3 vols (Volume 1: La documentation; Volume 2: Études de cas; Volume 3: Synthèse), Thèse pour le Doctorat d'État, Université de Paris I Panthéon-Sorbonne.

Hatzaki, E.M. 2005. *Knossos. The Little Palace* (BSA Suppl. 38), The British School at Athens, London.

Lowe Fri, M. 2011. *The Minoan Double Axe: An experimental study of production and use* (BAR International Series 2304), Archaeopress, Oxford.

McEnroe, J.C., C. Davaras & P.P. Betancourt 2001. *Pseira V: The Architecture of Pseira* (University Museum Monograph 109), University of Pennsylvania Museum of Archaeoogy and Anthropology, Philadelphia.

Meiggs, R. 1982. *Trees and Timber in the Ancient Mediterranean World*, Clarendon Press, Oxford.

Pakkanen, J. 2013. 'The economics of shipshed complexes. Zea, a case study', in D. Blackman, B. Rankov, K. Baika, H. Gerding & J. Pakkanen, *Shipsheds of the Ancient Mediterranean,* Cambridge University Press, Cambridge: 55-75. [online]

[Palyvou] Παλυβού, Κ. 1999. *Ακρωτήρι Θήρας. Η οικοδομική τέχνη* (Βιβλιοθήκη της εν Αθήναις Αρχαιολογικής Εταιρείας 183), Athens.

Palyvou, C. 2005. *Akrotiri Thera. An Architecture of Affluence 3.500 Years Old* (Prehistory Monographs 15), INSTAP Academic Press, Philadelphia, Pennsylvania.

Panagiotaki, M. 1999. *The Central Palace Sanctuary at Knossos* (BSA Suppl. 31), The British School at Athens, London.

Panagiotakis, N., M. Panagiotaki, D. Evely & Ch. Fassoulas forthcoming. 'Quarries in the Pediada Region in Central Crete', Πρακτικά 11ου Κρητολογικού Συνεδρίου (Ρέθυμνο, Οκτώβριος 2011).

Popham, M.R., J.H. Betts, M. Cameron, H.W. Catling, E.A. Catling, D. Evely, R.A. Higgins & D. Smyth 1984. *The Minoan Unexplored Mansion at Knossos* (BSA Suppl. 17), Thames & Hudson, Oxford.

Poursat, J.-Cl., M.E. Schmid, C. Éluère, M. Leduc & J.-P. Olivier 1996. *Fouilles exécutées à Malia. Le Quartier Mu III. Artisans Minoens : Les Maisons-Ateliers du Quartier Mu* (Études Crétoises 32), Paris.

Russell, B. 2013. *The Economics of the Roman Stone Trade*, OUP, Oxford.

Shaw, J.W. 1973. 'Minoan Architecture: Materials and Techniques', *ASAtene* XLIX, n.s. 33: 1-257.

Shaw, J.W. 2009. *Minoan Architecture: Materials and Techniques* (Studi di Archeologia Cretese VII), Bottega d'Erasmo, Aldo Ausilio editore in Padova.

Shaw, J.W. 2015. *Elite Minoan Architecture. Its Development at Knossos, Phaistos, and Malia* (Prehistory Monographs 49), INSTAP Academic Press, Philadelphia, Pennsylvania.

Shaw, J.W. & M.C. Shaw (eds) 1985. *Kommos I. The Kommos Region and Houses of the Minoan Town. Part 2. The Minoan Hilltop and Hillside Houses*, Princeton University Press, Princeton, New Jersey.

Shirley, E.A.M. 2000. *The Construction of the Roman Legionary Fortress at Inchtuthil*, (BAR British Series 298), Archaeopress, Oxford.

Soles, J.S. 1991. 'The Gournia Palace', *AJA* 95: 17-78.

Startin, W. 1978. 'Linear Pottery Culture Houses: Reconstruction and Manpower', *PPS* 44: 143-159.

Stocks, D.A. 2001. 'Testing ancient Egyptian granite-working methods in Aswan, Upper Egypt', *Antiquity* 75: 89-94.

Stocks, D.A. 2003. *Experiments in Egyptian Archaeology. Stoneworking Technology in Ancient Egypt,* Routledge, London & New York.

Tsakanika-Theohari, E. 2009. 'The constructional analysis of timber load bearing systems as a tool for interpreting Aegean Bronze Age architecture', in Kyriatsoulis A. (ed.), *Bronze Age Architectural Traditions in the Eastern Mediterranean : Diffusion and Diversity [Architektonische Traditionen im östlichen Mittelmeer während der Bronzezeit : Verbreitung und Vielfalt], Proceedings of the Symposium - Symposiumsband, 07.-08. 05. 2008 in Munich/ Gasteig München*, Herausgeber: Verein zur Förderung der Aufarbeitung der Hellenischen Geschichte e.V., Weilheim: 127-142. [online]

Wallace-Hadrill, A. 1994. *Houses and Society in Pompeii and Herculaneum,* Princeton University Press, Princeton, New Jersey.

Wulff, H.E. 1966. *The Traditional Crafts of Persia. Their Development, Technology, and Influence on Eastern and Western Civilizations*, The M.I.T. Press, Cambridge, Massachusetts & London, England.