Stone Tools related to Stone Masonry Techniques in the Eastern Mediterranean Bronze Age. An overview

Athina Boleti

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Ashlar

Exploring the Materiality of Cut-Stone Masonry in the Eastern Mediterranean Bronze Age

Edited by Maud Devolder & Igor Kreimerman

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9. Stone Tools Related to Stone Masonry Techniques in the Bronze Age Eastern Mediterranean

An Overview

Athina Boleti[1]

Introduction

The use of stone tools for cutting (quarrying) and dressing (shaping) stone for masonry (blocks and other architectural components) in the Bronze Age Eastern Mediterranean is a generally accepted assumption, but it has not been fully demonstrated. In the absence of sufficient corroborative archaeological, iconographic and literary data, evidence is largely based on use-wear analyses. The patterns and implications of the use of stone tools for producing ashlar architecture are hence not thoroughly assessed. The present paper aims to draw an overview of all available data on the subject, with a special emphasis on methodology, and to explore the use of specific materials, tools and techniques. These include percussive stone tools, composite tools used for abrasion such as saws and drills, and the exploitation and use of emery.

Stone tools can be used for percussion and abrasion. Percussive tools, which are considered here first, are of two types: (a) tools used in thrusting percussion – *percussion lancée* (Leroi-Gourhan 1943) or 'striking tools' (Wright 2005:52) and (b) tools used in resting percussion – *percussion posée* (Leroi-Gourhan 1943) or 'struck tools' (Wright 2005:52). Lithic materials can also be part of more complex tools or devices, such as saws and drills, either as cutting elements (drill bits, saw teeth) or, most often, as abrasives (powders and natural sands). The overview presented here mainly concerns the cultures that developed in Crete and the Greek mainland from the Protopalatial or First Palaces period (*ca.* 1900-1700 BC) to the end of the Mycenaean palatial period (*ca.* 1400-1200 BC). However, it inevitably takes into account the broader geo-cultural context of the Eastern Mediterranean from the 4th millennium BC onwards, in order to elucidate the origins, evolution and possible transfers of the practices here described.

Percussive stone tools

Egypt and Anatolia

The use of stone tools for cutting and dressing stone in different contexts (quarrying, masonry, sculpture, stone vase production) is well attested in Egypt from the 4th millennium BC onwards (Arnold 1991: 257-264; Goyon *et alii* 2004: 378-392; Harrell & Storemyr 2009: 25-29). Our knowledge in this field is largely based on the discovery of stone tools along with tool marks, while evidence provided from iconographic and literary sources is limited. Large quantities of different types of stone tools have been found discarded in quarries where the cutting of blocks, as well as the preliminary shaping of obelisks, statues and vases took place. The tools mentioned are picks, pick-axes, mauls (hammers), pounders, punches and chisels, and they can be handheld or shafted. These tools show varying edges and faces used in direct (thrusting) or indirect (resting, struck with another tool) percussion,

1 CNRS, UMR 7041 ArScAn, Protohistoire Égéenne. I would like to thank warmheartedly the organizers for a stimulating workshop giving the opportunity to exchange views on exciting topics. I am deeply indebted to Joseph Shaw for his comments on the Phaistos tool marks and permission to reproduce illustrations, Pietro Militello for information on the blocks from Ayia Triada, the photogrammetry of the reused block at Phaistos and permission to reproduce illustrations, Jean-Claude Bessac and Élise Morero for stimulating discussions, helpful suggestions, comments and bibliography, Élise Morero especially for sharing with me her expertise in drilling techniques, Nick Blackwell for exchanging views on tools and techniques of the Mycenaean period and providing me his unpublished PhD thesis, Pascal Darcque for useful discussion and Antonia Livieratou for her help and comments on drafts of the article. I would also like to thank the editors for their patience and for their feedback which was very constructive and helped to improve the presentation of this paper considerably. Any remaining errors are my own. I also owe many thanks to Françoise Rougemont, head of the Aegean Prehistory team (CNRS, UMR 4071 ArScAn) for covering travel expenses and supporting technically my research.

and they were chiefly made of hard stones, such as dolerite, greywacke, basalt, granite, as well as chert. There is a general agreement that they were used throughout the Bronze Age and even during the Iron Age up to the Greco-Roman period, mainly for quarrying and dressing hard stones (Arnold 1991; Goyon *et alii* 2004; Stocks 2003; Klemm & Klemm 2008). This conclusion is based on the physical and mechanical properties, mainly the hardness and durability, of the lithic materials used for percussive stone tools, which were significantly higher than those of available metal (copper, bronze, iron) tools. In several cases, as in the Northern Fayum quarries of the Pharaonic period, stones (diorite, granodiorite, Chephren gneiss, gabbro) used for tools found in the quarries are not locally available and were thus brought over from distant regions, sometimes up to 800 km away. According to Bevan and Bloxam (2016: 83, with bibliography), this phenomenon most likely reflects an intensive stone specialists' mobility, who brought their tools along with them to work on different projects. It is interesting to note that these imported tools were not used exclusively to quarry hard stones, such as basalt, but also for procuring gypsum – a soft stone. This clearly points to specific techniques and traditions and to a high level of specialization and organization.

Shaping stone by percussion – an activity mainly described as 'pecking' or 'hammering' – with stone tools, is also considered typical of imperial Hittite hard stone quarrying and dressing, for which bronze tools would not be resistant enough (Seeher 2011; Summers & Özen 2012: 514). Traces of these practices are reported at the Karakız Kasabası and Hapis Boğazı (Yozgat, Central Anatolia) quarries, dated to 1400-1200 BC, where numerous unfinished sculpted pieces were found (Summers & Özen 2012), at the Hittite Rock Sanctuary at Yazılıkaya at Boğazköy-Hattusha dated to the 13th c. BC (Alexander 1986: 27; Seeher 2011), and at 13th c. BC Fasillar in the Lake district of Turkey (Summers & Özen 2012: 514). At Yazılıkaya, stone hammers are thought to have been used for quarrying and for the first stages of shaping, while lighter stone hammers and metal chisels were used for the following dressing stages (Seeher 2011: 191-193). According to Alexander (1986: 27), these stone tools were made of basalt or emery-like stone. Tool marks created by the use of stone hammers are described as point-shaped and forming a dense network of white dots, unless they have been obliterated by polishing or weathering (Seeher 2011: 189). Based on experiments, Seeher (2009; 2011) suggests that patient pounding with roundish hammers could slowly wear down and pulverize the surface, just as Engelbach (1922) suggested for the Aswan obelisk in Egypt. Summers and Özen (2012: 512, 515) further distinguish morphological features linked to the use of stone tools, such as the lack of precision and the slightly rounded nature of all edges of the relief thus shaped. Alexander (1986: 28) also attributes these features to the use of stone tools, but he rather emphasizes shaping by rubbing. Stone hammers are reported from Boğazköy. They were either handheld or a hole was drilled through them to set them upon a relatively thin and springy wooden shaft (Seeher 2011: 189). Three fragments of stone hammers with drilled shaft holes – all made of hard igneous-stone river pebbles – were found at Karakız (Summers & Özen 2012: 514). More recently, the survey team of Harmanşah identified fragments of green gabbro hammers scattered across the marl quarry at the site of Yıldız Tepe near the village of Karaköy. Large ashlar blocks were extracted there for the construction of the well-preserved Hittite fortress of Kale Tepesi, only a few kilometers away. Numerous tools of this type have also been found in other Hittite sites (Seeher 2009: 125, n.22).

Aegean

In the present state of research, no clear association between stone tools and tool marks, of the kind available for the Egyptian and Hittite worlds, can be suggested for the Bronze Age Aegean. To the best of our knowledge, no stone tools have been found at the sites of extraction and dressing of ashlar components. Shaw (2009: 43-44, fig. 55.a-b) believes that natural stone cobbles, such as those found at Kommos, "could have been used to drive bronze chisels for either stone- or woodworking or, may themselves have shaped stones, as suggested by the pecking marks on the column bases from the Kommos stoas or those on blocks at Malia" on Crete. A Protopalatial (*ca*. 1900-1700 BC) date and reuse cannot be excluded for the column bases with pecking marks found in the Neopalatial (*ca.* 1700-1430 BC) Building T at Kommos (see in detail Shaw 2006: 91-96, pls 1.136-1.137), while Devolder (2018; 2019) also argues that some of the hard limestone blocks at Malia were first shaped with percussive stone tools and used in the First Palace, then reused in Neopalatial structures (Kreimerman & Devolder, this volume: fig. 1.19). The clearest identification of stone percussion tool marks on architectural stone blocks seems to come from the early Late Bronze Age settlement of Akrotiri at Thera, where stone hammers leaving

distinctive marks in the form of "tiny cavities" were used for dressing blocks and column bases of hard dacitic lava (Palyvou 2005: 113, 130). References to the use of stone percussive tools in Mainland Greece, especially in contexts dating to the Late Bronze Age, are even vaguer. 'Hammer dressing' of stone architectural elements in Mycenaean palaces, tombs and other constructions is often mentioned, based mostly on tool marks, and implies the use of percussive stone tools described as hammers (Küpper 1996: 7; Loader 1998: 47-48; for a recent account see Blackwell 2014: 454, n. 30, 31, with bibliography). Iakovidis' observations on construction techniques at the Acropolis of Athens are particularly noteworthy. He refers to "a blunt stone tool that left no trace on the rock and produced rounded edges and corners, employed to cut the trenches of the terrace walls" (Iakovidis 2006: 232), a description that fully meets that of Hittite sculptures with rounded edges mentioned earlier.

In the absence of specialized studies, there is not much information on stone tools that could be taken into account in the study of stone quarrying and building processes. The stone tools mentioned by Shaw at Kommos suggest the use of natural cobbles further shaped through use. In all Bronze Age phases at Kommos, Blitzer (2005: 426) indeed identifies a group of percussive stone tools suitable for stoneworking on the basis of their size, as well as the hardness and density of their raw materials. At the Bronze Age settlement of Sissi, Tsoraki (2012: 219) also distinguishes a similar group of percussive stone tools used in building/construction activities, *i.e.* percussive activities that required heavy impact force, on the basis of their size, weight and wear patterns. According to Procopiou (2013: 62), use-wear on percussive stone tools at Quartier Mu at Malia indicates that they were used for the first stages of stone shaping (for the production of architectural components or vases) during the Protopalatial period. At Protopalatial Phaistos (Chalara North), we have perhaps the closest stone equivalent to a metal pick-ax or adze, made here of a dark siliceous stone (Levi 1976: 675, fig. 1097). Several tools coming from Mycenaean contexts in Mainland Greece could have been used in masonry. Taking the example of Midea, Walberg (2007: 180) mentions rounded cobbles and handstones in marble, limestone, basalt, peridotite, chert and andesite. Based on their material, it can be reasonably assumed that these were used for dressing stone. Grossmann (1980: 496) is perhaps the only scholar who specifically refers to stone tools, mentioning that diorite stone pounders may have been employed for stone dressing at the Lower Citadel Wall at Tiryns[2]. However, in all the aforementioned cases contextual evidence confirming the use of these tools for shaping stone architectural elements is missing.

The use of percussive stone tools in the Bronze Age Aegean is thus first suggested on the basis of the presence or absence of tool marks. The lack of chisel marks (in the form of grooves of varying dimensions, see below) is indeed systematically referred to and it is considered indicative of the use of (presumably stone) hammers, mostly in the case of roughly shaped blocks. At Midea, for instance, Fitzsimons (2007: 90) notes that "where faces exist, the exposed sides of the stones are usually roughly worked probably with a hammer since there are no chisel or rasp marks visible on any of the exposed stones". Iakovidis (2006: 90) finds the lack of chisel or any similar tool marks at the foundation trench of the West Terrace Wall at the Acropolis of Athens notable. There, "rough spots in the surface of the rock have been simply removed, evidently with the hammer, to create a surface more or less level but hardly smooth". The use of stone hammers is also suggested based on the hardness of the worked materials. At the site of Akrotiri, Palyvou (2005: 113, 130) mentions the use of stone hammers for dressing blocks and column bases only of hard dacitic lava. Iakovidis (2006: 193, n. 307) mentions "clear traces of a narrow drove on a sandstone slab from the Mycenaean Acropolis of Athens, just like those on the façade of the tomb of Lions, that date the slab unquestionably to the Mycenaean times". He notes, however, that this tool could only be used on a very soft stone, since it was made of bronze. A clear link between hard stone building materials (limestone, marble, conglomerate) and percussive stone tools ('hammers') then seems to be established for the Late Bronze Age Aegean, particularly in Mainland Greece following trends familiar from Egypt and Hittite Anatolia.

Methodological considerations

Considering the research focus on tool marks, relevant methodology needs to be further addressed here. Experiments conducted so far leave no doubt about the efficiency of percussive stone tools for large-scale

2 Schliemann (1885: 74-75) also mentions tools of the same type at Tiryns: "dans la colonie primitive nous avons trouvé une douzaine des marteaux forts grossiers en diorite, pierre siliceuse ou granit, de la taille et du poids de ces marteaux on peut induire qu'ils ne s'adaptaient pas à un manche, mais qu'on les saisissait directement avec la main".

stoneworking activities, including quarrying and dressing masonry. Tests conducted since the beginning of the 19th century, from Engelbach (1922) and Zuber (1956) to Stocks (2003) for Egypt and Seeher (2011) for the Hittite Empire, indeed confirm the efficiency of stone tools compared with copper, bronze and even iron tools, which wear out too fast when used in similar stoneworking processes. As far as the Aegean is concerned, several experiments in marble working in the Bronze Age and later historical periods have demonstrated the efficiency of stone tools for dressing marble – a material not used in Minoan and Mycenaean masonry –, a stone of medium hardness (3.5 to 5 on Mohs scale). Oustinoff (1984) was the first to show the efficiency of emery percussive tools for shaping Early Cycladic marble figurines, which was further demonstrated by the recent reproductions of such artifacts using exclusively emery tools in order to evaluate the required know-how and degree of specialization (Papadatos & Venieris 2017). Experiments in the framework of the project *The Technology of Cycladic Marble*[3] aimed at a more global reconstitution of the manufacturing techniques of Cycladic marble figurines and vases and considered the use of a wider range of tools. Finally, experiments in the framework of the project *ToucherCréer*[4] focusing on the possible use of emery percussive tools for the shaping of Naxian Archaic marble *kouroi* (7th-6th c. BC) have also demonstrated the efficiency of percussion tools made of different stone materials (emery, diasporite, granite) (Procopiou *et alii* in preparation).

Klemm and Klemm (2008: 247) describe the function of percussive stone tools and their advantages:

> "*the sharp edges or corners of these stone hammers* [italics are mine] were used to break away the surface of the block by knocking away fine chips, or by grinding it away with the impacting weight of the stone hammer. This method made it possible to shape workpieces into the desired form layer by layer, treating the material very carefully, without placing heavy demands on the internal rock structure of the blocks themselves. This is one of the reasons for the great resistance to weathering of ancient Egyptian hard rock objects, which would not have survived even in the dry climate of Egypt if the surfaces of these objects had not been worked in such a careful and spare manner".

However, despite available experiments, it remains difficult to draw with precision the use patterns of percussive stone tools, especially when compared with the use of metal tools. This is also true for cases where archaeological finds testify to an extended use of stone tools, as in Egypt. Divergence in the identification of the same tool marks on soft stones (limestone and sandstone) quarries in Egypt is quite illustrative. Klemm and Klemm suggest the use of softer bronze chisels in the Old (*ca.* 2686-2125 BC) and Middle (*ca.* 2055-1650 BC) Kingdom and the use of harder bronze chisels in the New Kingdom (*ca.* 550-1069 BC) Egypt. On the contrary, Arnold (1991: 33-34 with bibliography; Stocks 2003: 79) sees the use of pointed stone picks or axes, already suggested by Engelbach, in the Old and Middle Kingdom and a new, but still unidentified tool in the New Kingdom. Based on archaeological and modern theoretical and empirical data, Bessac (1987: 21-23), asserts that it is almost impossible to distinguish between the traces of a metal and a stone pick. He believes that the use of hard stone picks in Bronze Age Egypt, as well as in Neolithic and Bronze Age sites in Southern France and in Corsica, can be reasonably assumed once again on the basis of the materials' properties, *i.e.* hardness and durability.

The above review outlines the framework against which tool marks have been interpreted until now. Except for Egypt, where a wider range of stone tools is considered possible, percussive tool marks seem to be distinguished into two main types in the Aegean and Hittite world: cavities/pits and grooves, both of varying dimensions and layout. It appears simpler to deduce the action that produced these marks than to identify the tool that created them. Pits/cavities result from a direct (thrusting) perpendicular percussion, while grooves are created by direct (thrusting) or indirect (resting) oblique percussion. Pounders, hammers and picks are generally considered to be used in the first manner, and picks, points and chisels in the second manner. In this sense, the ubiquitous term 'hammer' used in Late Bronze Age contexts refers to the action (direct/thrusting percussion set perpendicularly to the surface) rather than to a specific type of tool. The different types of metal hammers known from 2nd millennium BC as well as later historical contexts present smaller or bigger flat/rounded edges (see for example Evely 1993: 97, 109 for Minoan contexts) unsuitable for producing the type of pits/cavities generally found especially without weakening or breaking the stone. Interestingly, some of these metal hammers are thought to have been originally axes, adzes or picks used as hammers once the pointed or sharp edge went blunt and flat (see for example Blackwell 2011:

3 National Archaeological Museum & Museum of Cycladic Art in Athens: https://www.cycladic.gr/en/page/research
4 Université Paris 1, CNRS UMR 7041, ArScAn, Protohistoire Égéenne.

172-175). To sum up, as it is explicitly demonstrated in Bessac's (2004: 19-28) overview of stone cutting/dressing tools, a sharp/pointed edge is the *sine qua non* feature of percussive tools especially for thrusting percussion. These tools and their marks are then further determined by a series of parameters, such as the different forms of the edge, the presence or the absence of a shaft, the weight and the physical and mechanical properties of the material, the type of percussion (direct/indirect percussion), the angle and the strength of the stroke.

The debated case of the rounded stone pounders known from Egypt also demonstrates that the percussive stone tools used for shaping stone were mostly sharp-edged/pointed. These tools are thought to be originally more or less spherical and to be used handheld in direct percussion mostly in vertical strokes so that they crush or pulverize the stone that is removed in a rather long process. This view is drawn from the thousands of rounded pounders found at the Unfinished Obelisk granite quarry at Aswan as well as in other Egyptian quarries and sites. Klemm and Klemm (2008: 240-241, fig. 364) very pertinently observe that the spherical/rounded form of the Egyptian pounders is most probably the result of the use of initially naturally broken, angular/sharp-edged, pieces. Kelany *et alii* (2010) provide further indication that these pounders result from the use of originally sharp-edged stone tools, underlining the fact that angular dolerite pounders were originally present at the Unfinished Obelisk granite quarry at Aswan, but that they were not recognized as ancient tools and were discarded during excavations. Recent discoveries at the Aswan quarry (Kelany *et alii* 2009: 90) also seem to confirm the hypothesis originally set out by Goyon (1976) who suggested that thermic treatment by heating that resulted in the exfoliation of the rock, was used to facilitate granite cutting. In this case, the effect of heat on the granite surface must also be taken into account for the formation of the marks (Heldal & Storemyr 2015). Seeher (2009: 125-126) too notes that Hittite rounded pounders must have been originally pointed/sharp-edged pieces. Technically speaking, we can thus envisage the use of rounded pounders mostly for leveling/finishing surfaces, in other words for crushing asperities remaining after cutting and dressing processes have first taken place, but not for working the stone by taking off considerable quantities of material. As Bessac (1987: 19) clarifies, "le percuteur sphérique mâche la pierre plus qu'il ne la pique et ses traces, après quelques siècles, sont très effacées par l'érosion".

Concerning the second main type of tool marks, *i.e.* grooves, these are often automatically considered to be produced by metal tools, mainly picks used in direct thrusting percussion or points and chisels used in indirect resting percussion at an oblique angle. However, the production of grooves as marks by the same use of sharp-edged stone tools, shafted or handheld, cannot be entirely excluded. Recent experiments (Procopiou *et alii* in preparation) have shown that sharp-edged handheld tools can also produce more elongated traces, when used at an angle instead of perpendicularly to the surface. More interestingly, they demonstrated that the use of stone (diasporite) pointed splinters in indirect percussion at an oblique angle on marble produced similar groove marks as metal points. Moreover, while in some cases marks described as scratches – here falling into the broader category of grooves – suggest the use of metal punches or points used in indirect percussion (Evely 1993: 213), these tools seem to be related to small crafts in 2nd millennium BC Aegean contexts (Evely 1993; Blackmann 2011). Finally, while it may be difficult to accept that stone tools with more elongated/flat cutting edges used in direct percussion (*e.g.* axes or adzes) or indirect percussion (*e.g.* chisels) could have been efficient enough for stoneworking, possible examples exist in Egypt (Goyon *et alii* 2004: 391; Bloxam *et alii* 2014), and some experiments invite us to further explore this possibility. Brenet *et alii* (2001) demonstrate the use of chert adzes to dress 'cigar-shaped' building stones out of limestone in a considerably earlier and different geo-cultural context (Pre-Pottery Neolithic A Middle-Euphrates sites, 10000-8800 BC). Most importantly, Stocks (2003: 77-79) argues through his experiments that in Egypt flint chisels were more cost-saving than metal ones in the case of cutting hieroglyphs into hard rocks such as porphyry and granite, a task for which even steel tools available in the Roman period would be badly damaged.

To conclude, this methodological overview of stone tools used in stoneworking shows that the identification of percussive stone tools in terms of tool marks is more complicated than initially surmised. It goes beyond a simple distinction between stone hammers/pounders used in direct vertical percussion and producing bigger or smaller pits, and metal picks, points, axes/adzes, punches and chisels, used in direct or indirect oblique percussion and producing grooves of varying morphology and layout. Based on the considerations stated above, we may contemplate a much wider use of stone tools, including both shafted or handheld tools, used in direct or indirect percussion, perpendicularly or at an oblique angle to the surface, just as is the case with metal picks, points, punches and chisels. Data produced by the study of metal tools (Evely 1993; Blackwell 2011) seem to corroborate a more widespread use of percussive stone tools for quarrying and dressing stone. Picks, which are considered to

be one of the quarryman's and mason's principal tools mainly in historical periods, are rare and unattested in the 2nd millennium Aegean apart from a few examples from Neopalatial and Final Palatial Crete (*ca.* 1700-1360 BC) (Shaw 2009: 41; Blackwell 2011: 176). These include badly damaged specimens that could have been used for stoneworking (Evely 1993: 72) in addition to agricultural tasks and woodworking. On the contrary, axes and chisels, that could be used both for carpentry and soft stone dressing, are the best represented tools (Evely 1993; Shaw 2009; Blackwell 2011). The state of evidence thus indicates a strong complementarity between metal and stone tools.

Several factors may account for the lack of archaeological evidence concerning percussive stone tools used in masonry in the Bronze Age Aegean. First, these tool assemblages "were largely ignored until recently because of their humble character" (Evely 1993: 109; Shaw 2009: 43). Second, difference in scale of construction and mobilization of working forces as compared with Egypt may also have impacted the visibility of stone tools. In the Aegean, we do not expect to find the large heaps of discarded tools known from the Egyptian quarries. The long distances over which the stone tools had to be transported, as well as the abundant quantities of raw material at disposal may also explain why these were discarded more easily in Egypt. Finally, and perhaps most importantly, the nature of the tools themselves may account for this phenomenon. Stone tools are often multifunctional. They can be reused (reshaped or not) in other *chaînes opératoires* and activities, alternatively or successively (Evely 1993: 109; Blitzer 1995: 404; Adams 2014: 24-28). Imported stones especially, like emery, were precious materials and would have been reused in other contexts and activities of different scales (from masonry to small crafts), very possibly until exhaustion. Therefore, stone tools, just as metal tools, were not left over *in situ* at the quarrying and construction sites but were carefully kept in order to be reused. They are thus to be found in other, domestic and artisanal, contexts, often along with metal tools, when they are not stored in special locations. Here again, while a metal tool is cast once with a predetermined form and function and has to be re-melted and recast to take another form, stone tools may have several parallel or successive lives without particular modifications, not all of them leaving traces in the archaeological record. Taking into account all the above, we have to consider a more substantial and manifold role for stone tools in masonry practices in the Bronze Age Aegean. Percussive stone tools can also indicate technological traditions and cross-cultural interaction. In this sense, different trends pointing to distinct technologies (*e.g.* large handheld pounders in Mycenaean sites, mainly drilled and shafted hammers in Hittite sites) merit to be further studied. A new, holistic and larger scale approach is required in order to understand all these aspects. Given that the efficiency of stone tools for stoneworking is proven, we now need to assess in detail their cost/gain efficiency, their patterns of use and associated technological traditions in societies that already used metal.

Composite tools used for abrasion

A clearer picture can be drawn for the use of abrasive stone tools and materials for dressing stone in the Bronze Age Aegean, despite limited and dispersed evidence. Lithic materials can be used for abrasion in two ways. First, they can be used in the form of compact tools, such as rubbers and polishers. These are mostly required in the final stages of leveling and smoothing and are attested rather randomly in dressed stone masonry. Therefore they will not be further considered here, although Casson (1933: 194; see also Boleti 2017: 37-38) convincingly argued that emery rubbers and similar abrasive tools were used for shaping marble in the Bronze Age (Early Bronze Age figurines, 3rd millennium BC) and in later periods (Archaic sculpture, 7th-6th c. BC). Secondly, abrasive lithic materials were used in powder form with saws and drills. In this framework, the use of specific abrasive materials can be enlightening with regard to techniques, related traditions and transfers. We shall hence focus here on this topic.

Saws

Tool marks suggest that saws consisting of shafted bronze sheets were used for cutting blocks, thresholds, paving slabs and column bases, especially of hard stones, at least from the Middle Minoan III onwards (*ca.* 1700 BC), while some of the largest saws found in the Aegean (and the wider Mediterranean) support this use (Shaw 2009: 46-

51; Evely 1993: 26-40. See also Stocks 2003: 135, on the need for wooden frames). However, according to Shaw (2009: 46), the use of saws for cutting large squared wall blocks of soft stone (poros limestone and sandstone) in Minoan Crete remains largely hypothetical and rather overestimated. Palyvou (2005) does not mention any saw cutting marks from Akrotiri on the island of Thera in the Cyclades. Numerous saw cutting marks attest to a wide use of saws for cutting hard stones, such as conglomerate, in Mainland Greece during the Mycenaean palatial period (14th-13th c. BC), although saw blades themselves are relatively absent from the archaeological record (Blackwell 2011; 2014; 2018; this volume). As far as Egypt is concerned, archaeological finds are lacking. Tool marks and iconographic evidence indicate that they were used, though rarely, for dressing soft as well as hard stones, but never for quarrying stone (Goyon *et alii* 2004: 393). Bevan and Bloxam (2016: 83) are inclined to interpret this as evidence of a specialized and controlled use of these highly valued tools.

Saws used for cutting stone were most likely toothless and used with an abrasive (natural sand or ground minerals). In this operation, stone was cut by the abrasives put into action by the back-and-forth movement of the saw's blade. This assumption, following modern masons' tools, was originally developed by Petrie, then further illustrated by Stocks' experiments with quartz sand and is now generally accepted (Bessac 1987; Arnold 1991: 267; Evely 1993: 26; Stocks 2003; Shaw 2009: 49). It is also based on the simple observation of the rate of use-wear of copper alloy in such operations, a factor which should not be neglected. Arnold (1991: 267) considers that the loss of metal must have been considerable even when abrasive powders were used and that the method was so expensive that it was only carried out for the construction of royal monuments. However, it should be noted that most of the known archaeological examples are toothed, which suggests they were rather used for woodworking. Only four untoothed examples are mentioned from Neopalatial Crete, two from Ayia Triada and two from Zakros (Evely 1993: 33; Shaw 2009: 50). Petrie's suggestion of a composite saw with emery bits fixed on a bronze blade remains highly hypothetical, since no such tool was ever found, at least in the Aegean Bronze Age. Petrie came to this conclusion during a visit at Tiryns where he found a corroded piece of bronze and small, 0.16 cm-long ("1/16th inch"), pieces of a black material in a saw cut on a limestone block. The black material was identified as emery at the Department of Mineralogy of the British Museum, and Petrie argued that the pieces were too big to be used as abrasive powder and should thus have been fixed on a bronze blade (Dörpfeld 1885: 247-248).

Drills

Drills are composite tools with a central axis, most probably a piece of wood or reed (for drills' typology and function see Bessac 1987; Evely 1993: 77-82; Stocks 2003: 103-138; Bevan 2007: 44-45; Morero 2016). Their cutting edge can be solid (the wood itself or a fixed drill bit made of stone or metal) or hollow/tubular (the reed itself or a fixed metal tube). It is put in rotation either by being twisted between the palms or by the use of different types of mechanisms, such as bows. The adjunction of an abrasive in the form of powder or sand is considered necessary for cutting, following the same principle as for saws. There is general agreement that cutting is performed by the abrasive put in action by solid or flat-edged tubes in rotation, with the exception of Petrie's general conviction that, just as he suggested for saws, jewel points were set into copper tubes and blades and did the cutting without the adjunction of abrasives (Petrie 1884; see Stocks 2003: 108-109 for a synthesis). The principle of mechanical drilling was already well known in the Eastern Mediterranean as early as the Neolithic and the Early Bronze Age (7th-3rd millennium BC). It is used for hollowing out stone vases in the 7th millennium in the Near East, in the 6th millennium in western Anatolia, in the 4th millennium in Egypt and the Cyclades and in the 3rd millennium on Crete (from EM II or *ca.* 2800 BC onwards). The tubular drill seems to have been first used on a large scale in stone vase production in Predynastic Egypt (4th millennium BC), its use in other regions being limited to perforating stone maces, axes, hammers and beads (Morero 2016: 225-226, with bibliography). Evidence for large-scale use of tubular drills in the Bronze Age Aegean mainly comes from Crete, where tubular drills were widely used, along with drills with a solid bit, for hollowing out stone vases as well as for seal cutting and engraving from Early Minoan III/Middle Minoan I to Late Minoan IIIB-C (*ca.* 2200-1070 BC) (Evely 1993: 73, 84). The tubular drill was most likely introduced to Crete from Egypt (Morero 2016: 226-228).

Despite abundant evidence for a wide use of drills in other stoneworking fields in the Bronze Age Aegean, evidence for their use in masonry remains limited. The tubular drill was used from the Protopalatial period onwards for cutting mortises in hard stones, as is for example the case on the reused orthostates blocks of Chrysolakkos

at Malia (Shaw 2009: 51). In Mainland Greece, the tubular drill was used in Mycenaean architecture during the palatial period (14th-13th c. BC) for cutting mortises in hard limestones and conglomerate at the Palaces of Tiryns and Mycenae and at the Atreus Treasury, as well as for sculpting the Tiryns throne base, fragments and columns of the Treasury of Atreus and the Lion Gate relief at Mycenae (Küpper 1996; Blackwell 2014). Evidence for the use of the tubular drill in these cases consists of holes of limited depth and the mark left at the bottom of the holes after breaking and removing the bore core.

We only know of one block with marks of cutting with a tubular drill: a limestone quadrangular block (inv. 1088, 38 x 35 x 18 cm) apparently reused as filling material in Late Minoan IIIA2 (*ca.* 1360-1330 BC) foundations in the northeastern area of the Ayia Triada site on Crete (La Rosa 1987: 387-389, tabl. II-III; Lazzarini 2001: 576-579, figs 1-3)[5]. Several parallel grooves of a length ranging from 15 to 25 cm and a maximum estimated diameter of 3.2 cm can be distinguished on four sides of the block (**Fig. 9.1**). These are disposed in two clusters meeting towards the middle of each face, indicating that drilling was bidirectional, *i.e.* that it was conducted from the two opposite edges of the same face. At least three fragmented bore cores are still visible undetached. La Rosa (1987: 388) considered it unlikely that the block was used by local apprentices to practice on hollowing out blocks by drilling. Indeed, experiments show that this process does not require extended apprenticeship. The risk of fracture during this operation is also rather limited, and training could simply have taken place through vase production (Élise Morero, personal communication). Moreover, if the block was intended for practicing, we would expect to find drilling tests in the middle of the block, not on its outer and side faces, and the drillings would not necessarily be aligned. There seems to be here a clear intention to dress or completely cut the block. La Rosa (1987: 388-389) suggests that the block was cut off by drilling from/in a larger block and was then removed, thus creating a sort of mortise in the latter. Such an assumption in not unreasonable, although the nature and function of the tenons inserted in the mortise, most probably for fixing a wooden beam, remains hypothetical. The block in which the mortise was cut, was an important construction component representing a considerable investment in terms of quarrying, shaping and transport, and drilling would have been favored to minimize the breaking risk. The block attests thus to drilling techniques applied in masonry practices (see also Morero 2016: 245-246).

Evidence from Egypt indicates that drills were used for cutting stone in masonry, though mostly at the end of the Early Dynastic period (*ca.* 3000-2686 BC) and in the Old Kingdom (*ca.* 2686-2125 BC). Lauer (1936: 234-235; 1974: 199) mentioned traces of drills with solid bits made of chert for dressing limestone in the earlier monuments (capitals of fluted columns at the "Heb-Sed court", Boundary Stelae reused in revetments, blocks at Mastaba M2, discarded blocks) of the Djoser complex at Saqqara (late Second/early Third Dynasty, *ca.* 2890-2686/2686-2625 BC). However, this method for dressing stone was used randomly for the later monuments of Djoser's complex (Pyramid and other monuments within the enclosure), and Lauer suggested that it was abandoned because it was very time-consuming. If we take into account that these are considered to be the first monuments entirely erected in stone, the above pattern of use of drills for cutting and dressing blocks may well illustrate a period of experimentation where techniques already mastered for stone vase production were applied and tested in masonry. The huge stores of stone vessels made of alabaster and other hard stones discovered in the galleries of the tombs of the royal family at Djoser's complex attest to the production of stone vases by drilling, some of the specimens reaching 1 m in height (Lauer 1974: 138). Traces of tubular drilling along with coloration generated by the use of a copper drill are also attested on a stone block from the Fifth Dynasty mortuary complex of Nyuserre at Abusir (*ca.* 25th c. BC) (Stocks 2003: 108). Moreover, Petrie (1883: 176) mentioned that at El Bersheh "a platform of limestone rock has been dressed down, by cutting it away with tube drills of about 18 inches [45 cm] diameter, the circular grooves occasionally intersecting, prove that it was done merely to remove the rock" (see also Arnold 1991: 265-266; Stocks 2003: 108). This platform, if contemporary with the Twelfth Dynasty (*ca.* 1985-1773 BC) monumental tombs in front of it, could attest to the continuity of this practice in the following period (Middle Kingdom, *ca.* 2055-1650 BC). Evidence for drilling from the New Kingdom (*ca.* 1550-1069 BC) is also absent from quarries and scant in construction sites. It is attested by some parallel drilling grooves (diam. 4.5 cm) with bits of bore cores found in position on a granite block dating to the reign of Thoutmosis III (15th c. BC) at the Red Chapel of Hatshepsut (Burgos 2008: 40-41, fig. 14). Drilling in architecture is thus thought to have been limited to the production of holes for pivots, door bolts, round cramps, nails for the application of sheet metal and

5 Pietro Militello has kindly brought to my attention the existence of a second block with tubular drilling marks from Ayia Triada.

the insertion of emblems (Arnold 1991: 266). The main reason for a limited use could be the need for considerable quantities of metal for the tubular drills that worn out quickly during the process, just as the case was for saws (Arnold 1991: 50, 265).

However, evidence from the First Palace at Phaistos may corroborate a longer use of drills for cutting stone in Minoan masonry and establish an extra link between Egyptian and Cretan practices. The somewhat perplexing tool marks on the poros limestone orthostates of the West Façade of the Palace at Phaistos could point to drilling practices (**Fig. 9.2**). The horizontal, almost parallel ridges seen on the orthostates' outer face, first described as undulations by Pernier (1935: 184-185), are similar to the ridges of residual grooves of drilling of the type seen on the aforementioned block at Ayia Triada. They seem, however, to have been further cut off by picks or chisels whose marks could match with the parallel striations seen obliquely to the ridges. Shaw (2009: 52) suggests that the horizontal ridges were produced when the direction of cutting with chisels or points changed. It is indeed very unlikely that these marks were produced by double axes or saws, as suggested by Pernier (1935: 184; Shaw 2009: 52), while the use of points and chisels, or even picks, can account satisfactorily for the parallel striations. However, the ridges do not seem to have been produced by these types of striking tools, while in many parts the striations overlap the ridges, thus pointing to an intention to obliterate them perhaps before applying plaster on the surface (**Fig. 9.3**). The grooves themselves, though very shallow (a few mm) at the actual state of preservation, are not of a rectangular/angular section, as one would expect if they resulted from the use of a striking tool with a wide flat blade (chisel, adze), but rather present a more rounded section. Similarly, the use of a sort of gouge, a tool with a concave blade, would produce grooves of a more standard width in a layout corresponding to the successive strokes.

On the contrary, the use of a tubular drill would be a better explanation for the grooves running along the entire outer face of the orthostates, best seen in old photographs (**Fig. 9.2**) (Pernier 1935: 184, fig. 77; Shaw 2009: figs 62e, 62f, 85-86, 88). Drilling can also account for the wavy outline of these grooves, as it would have been executed in steps due to the need to stop and evacuate drilled material, *i.e.* cores and debris/slurry, replace drill bits, and add abrasives and lubricants (Morero 2016: 127-128 for related experiments). Drills can deviate from a straight line when drilling restarts after an interruption, but also during drilling. Traces left from drilling, mainly striations, are generally leveled with striking tools, in parts coated with plaster, or weathered by taphonomic conditions and further erosion after excavation. But the diameter of the grooves, 4 cm on average, is consistent with the examples of tubular drilling known for the Protopalatial period. The maximal length of the orthostate blocks of the Phaistos Palace slightly exceeds 3 m in some cases based on the published plans (Pernier 1935: tav. II; Levi 1976: fig. 1; Carinci & Baldacci 2017: fig. 2). If we suppose a bidirectional drilling, as in the case of the Ayia Triada block, drilling does not need to go deeper than 1.5 m, which is technically feasible if one considers 3rd millennium BC Egyptian stone vase making and the relative softness of poros limestone. A bidirectional drilling would have made it possible for two teams to work simultaneously by drilling a block horizontally. This method is close to that of the lathe or running drill used in Classical Antiquity for sculpture and seal cutting (see for example Palagia 2006: 258-260) and is suggested for Minoan seal cutting already since the Protopalatial period (*ca.* 1900-1700 BC) (Krzyszkowska 2005: 83-85). In the Phaistos case, both the block and the drill – which was most likely activated with a bow – would be set in a horizontal position. Horizontal drilling has been tested successfully for hollowing out a stone vase with a bow drill with a solid stone bit (Morero 2016: 133-136, 222), and the same technique can thus be suggested for the Phaistos orthostates. The fact that the craftsmen repeatedly chose to drill along the longest axis of the blocks clearly shows that they mastered the technique well enough to go after the most elongated form possible. An isolated block (L. 139 cm max., h. 47 cm) reused in Corridor L of the Phaistos Palace and published by Shaw (2009: fig. 62f) may be closer to the example of Ayia Triada and better illustrates drilling practices for dressing stone blocks (**Figs 9.4-9.5**). On the outer face of the block, the same grooves that were assumed to be issued by drilling, end here in the shape of "arcades" that may correspond to the bottom-end of the drilling. The parallel oblique striations visible all over the grooves may again indicate the leveling of the surface and the erasing of the drilling marks by cutting with a percussive tool.

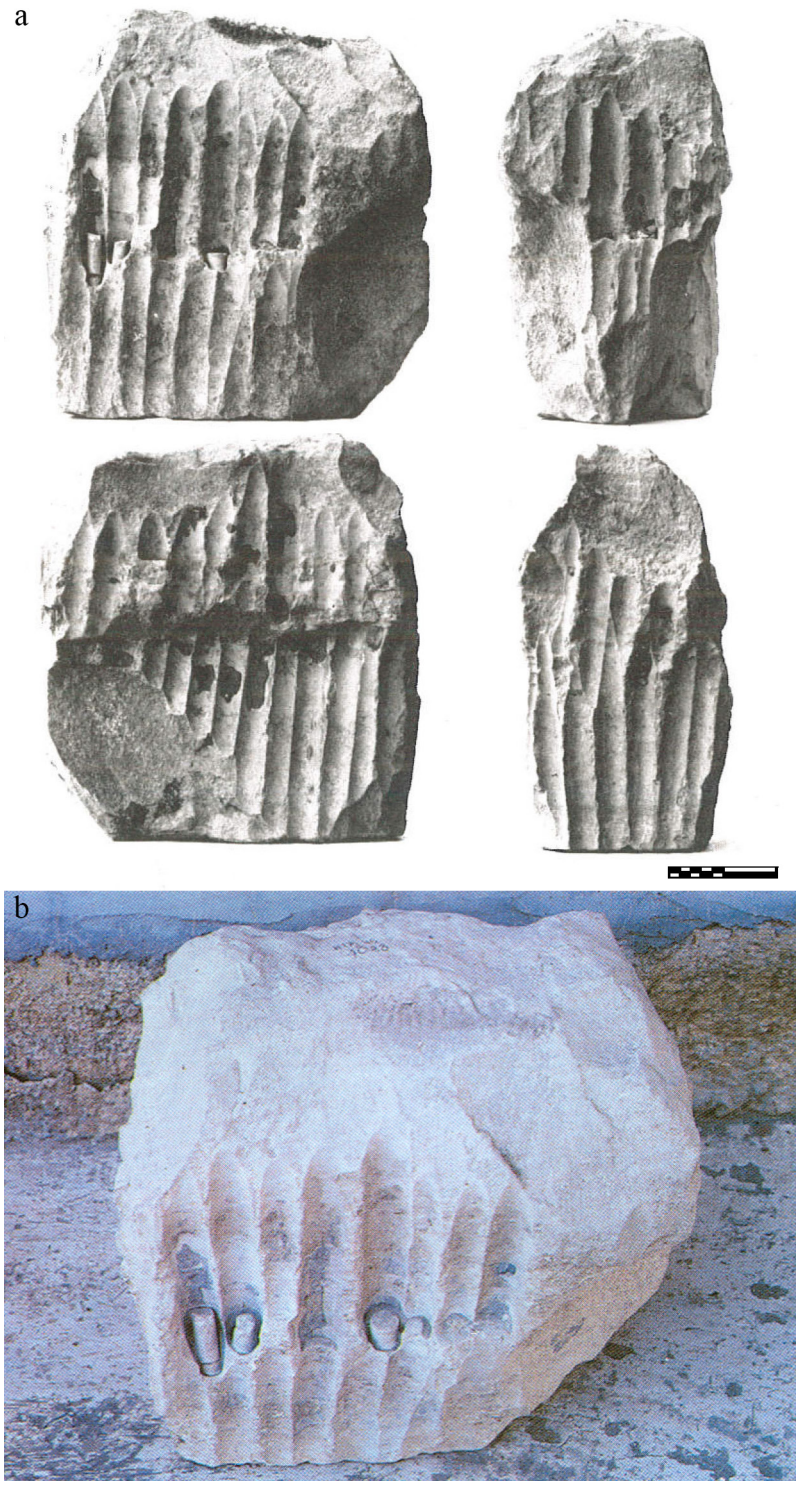

FIG. 9.1 VIEWS OF THE AYIA TRIADA BLOCK (A: LA ROSA 1987, PL. II; B: LAZZARINI 2001: FIG. 1)

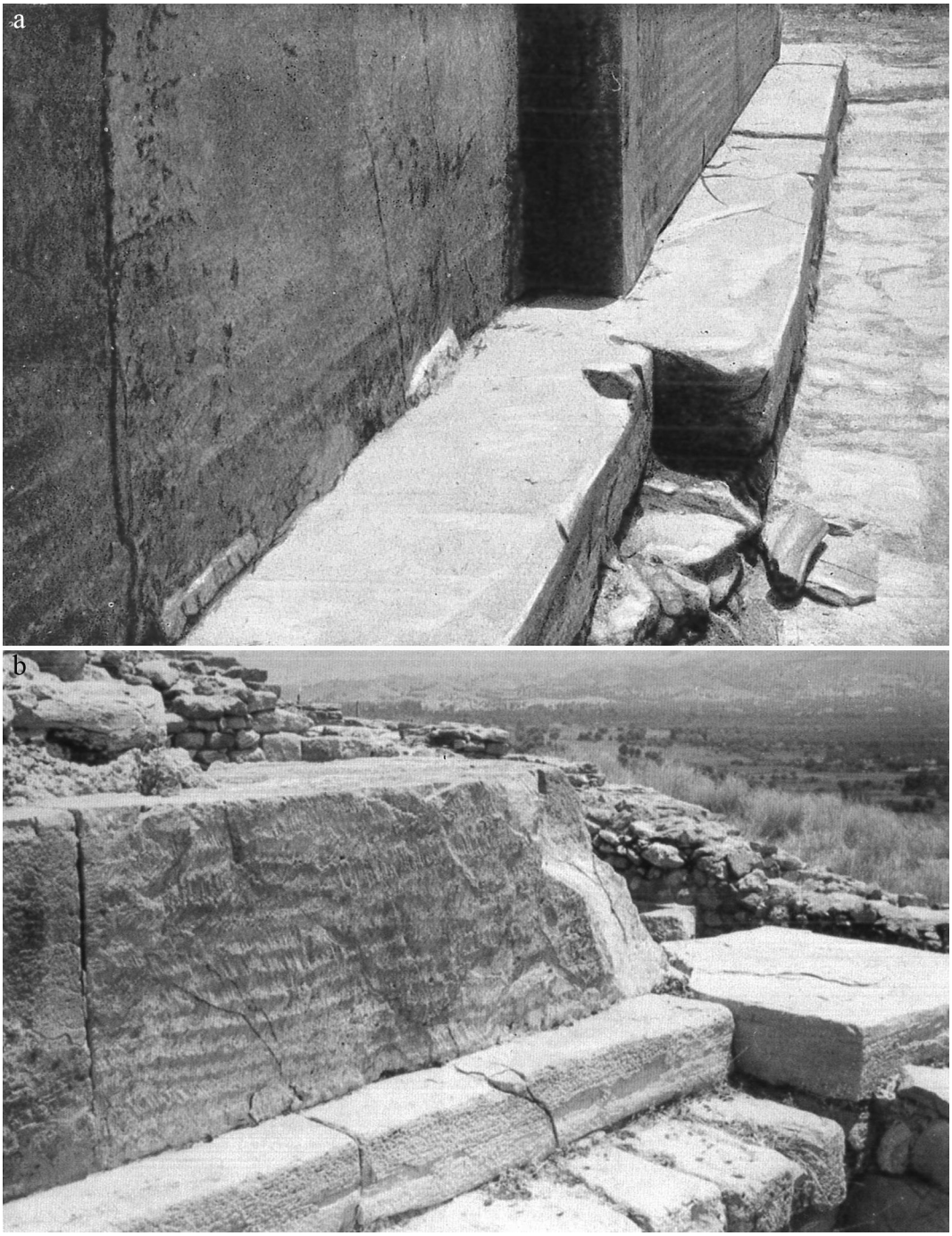

Fig. 9.2 Detailed views of orthostates in the west façade of the First or Protopalatial Palace at Phaistos: Middle West Court (northern part), with remains of plaster coating visible at the base of the blocks (a) (Pernier 1935: 184, fig. 77); Lower West Court (southern part) (b) (Shaw 2009: fig. 86)

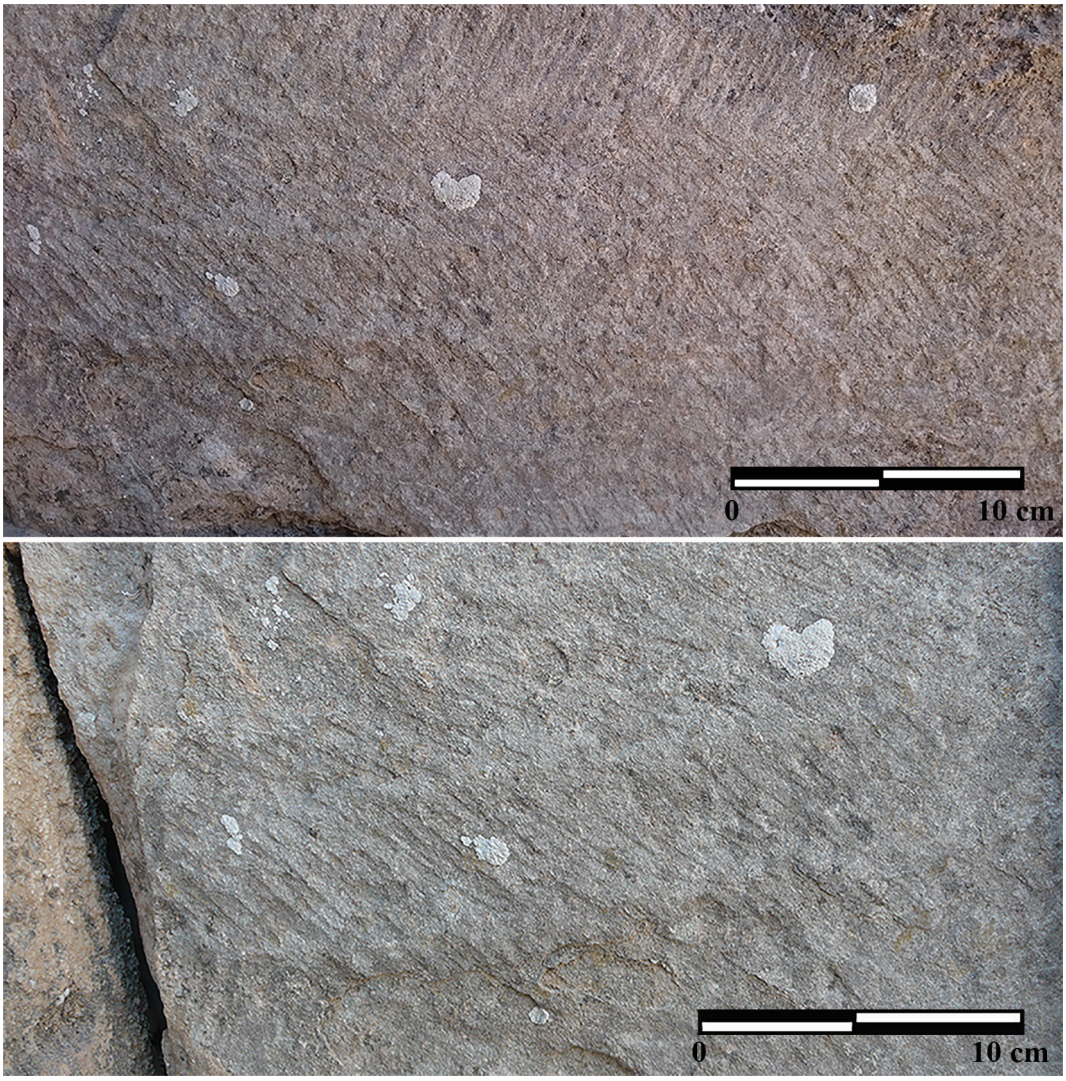

Fig. 9.3 Detailed views of the orthostates in the Middle West Court of the First Palace at Phaistos, showing parallel oblique striations overlapping the ridges that separate the large parallel grooves (courtesy of P. Militello; photographs by the author)

Based on the above observations, we can deduce that the masons at Phaistos made a very specific choice of cutting large poros limestone blocks destined to be used as orthostates by drilling. It is even more likely that they split in thickness the original blocks in two equal smaller ones. A detailed study of grooved tool marks could confirm this hypothesis, especially if symmetric traces are identified on two distinct blocks. The advantage of this method would be that large solid volumes of rectangular shape could be obtained with a minimum risk of breakage and with the highest possible precision. Performing such a cutting with percussive tools would be more risk-taking given the proportions and the elongated form of the orthostates (height of almost 1 m and average width of 0.65 m, Pernier 1935: 184-185, max. length of 3 m) and would provoke the loss of much more material. It seems likely then that drilling would be the most cost-saving method in terms of materials, time and energy, given that sufficiently large-sized, operational saws are not assumed to be available in Protopalatial Phaistos. It remains difficult to fully reconstruct the above operations in the absence of a detailed study of the tool marks. However, if the above hypothesis is proven right, we may have to deal not just with a style specific to the Messara region, as argued by Shaw (2009: 52), while providing evidence from Kommos as well (Shaw 2009: 52; 2006: 89, pl. 1.139), but also

with a technique possibly carrying on until the Late Bronze Age. Evidence from Kommos consists of a block possibly belonging to an ashlar façade set above the wooden architrave at the Neopalatial North Stoa. Based on the similarity of the tool marks with those on the orthostates of Phaistos (parallel grooves overlapped by striations from striking tools), Shaw considers that the block belonged to the Protopalatial Building AA and was reused in the Neopalatial stoa, but mentions that the block best fits in the ashlar masonry of the Neopalatial period.

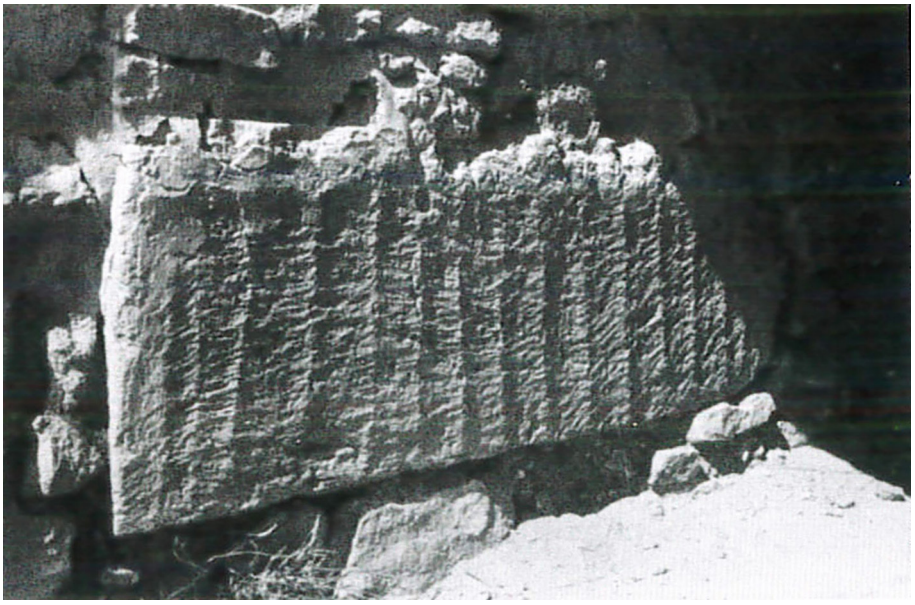

FIG. 9.4 PHAISTOS PALACE. REUSED BLOCK IN THE NORTHERN WALL OF CORRIDOR L (SHAW 2009: FIG. 62F)

This technique may also illustrate the influence of Egyptian stone drilling practices on Cretan masonry, expanding the already existing account of contacts between Crete and Egypt (see for example Karetsou 2000; Phillips 2008; Wiener 2013; Garcia 2014). Cross-craft interaction is evident here just as in Egypt. Although orthostates are indeed rare in Egypt and are considered mostly typical architectural features in other regions of the Mediterranean (Aegean, Levant, northern Syria and Anatolia), stone slabs standing on end used to face the lower part of walls and the general principle of case-mating are known in Egypt especially in the Old (*ca.* 2686-2125 BC) and Middle (*ca.* 2055-1650 BC) Kingdoms (Arnold 1991:164). The function of these architectural components in Egypt (revetments) is clearly different from that of the orthostates, but they both share the same technical principles (large slabs standing on end). Selective adoption of foreign technical elements and adaptation to local style and needs as reflected in the case of the Phaistos orthostates would then be consistent with the general trend attested in Minoan crafts.

The Ayia Triada block constitutes our most concrete evidence for drilling practices with regard to masonry techniques. This specimen could be considered as evidence of practices applied by the Mycenaeans, who favored the use of sawing and drilling in hard stone masonry and sculpture, and thus it could further support the hypothesis of Mycenaean influence on the architecture of the Messara region (Shaw, this volume). However, it is very likely that the block is of an early date and was later incorporated in the Late Minoan IIIA2 foundations (Pietro Militello, personal communication). In fact, the longstanding Minoan tradition of systematic tubular drilling for stoneworking (seals and vases) cannot be overlooked, even if the question of cutting techniques attested on the orthostates at Protopalatial Phaistos, still not clarified, and the dating of the blocks from Kommos and Ayia Triada are left aside. Tubular drilling was certainly a technique perfectly mastered by the Minoans, applied in hard stones working on different scales, from seals to large vases during the Neopalatial period (*ca.* 1700-1430 BC). Hard stone seals engraving (and perforation) also continues in Late Helladic IIIA (*ca.* 1390-1330 BC) (Younger 2012), while the marks of the tubular drill on seals can be detected until into Late Minoan IIIB-C (*ca.* 1330-1070 BC) contexts on Crete (Evely 1993: 84). Given the problems of dating concerning seals of the Late Minoan IIIA-B period (*ca.* 1390-1190 BC) (Evely 2000: 166; Krzyszkowska 1995: 199), evidence from the field of stone vase

production is more conclusive as far as the latest use of the tubular drill is concerned. Tubular drilling continues in the Mycenaean Greek mainland for stone vase production until at least the Late Helladic IIIA period (*ca.* 1390-1330 BC), even though it seems to be adapted to local shapes, technology and tool kits, as pointed out by Morero (2015: 21-23). More precisely, a use pattern specific to Mycenaean workshops differing from Minoan practices known until then appears to be developed. A single tool approach (the tube is the only drill bit used) is adopted for hollowing out the vases and for drilling the holes for the inlay decoration, in combination with loose abrasives, while the drill is also held in horizontal or oblique position (Morero 2015: 10-14). This pattern can be tracked down to Late Helladic IIIB1 (*ca.* 1330-1250 BC), as illustrated by a jar from Mycenae (Wace 1955: 182, pl. 23b).

FIG. 9.5 PHAISTOS PALACE. REUSED BLOCK IN THE NORTHERN WALL OF CORRIDOR L, IN CONTEXT AND DETAIL (PHOTOGRAMMETRY BY F. BUSCEMI)

Thus, the idea of a Cretan origin for the drill employed in Mycenaean masonry is consistent with all the available data and fits well in the general interpretative framework regarding the origins and evolution of Mycenaean masonry, reserving a dominant part to Minoan agency (see Wright 1978; this volume; Nelson 2007; Bevan & Bloxam 2016). On the basis of a generally accepted cross-craft interaction, *i.e.* the principle/practice of tubular

drilling remains the same in seal engraving/perforation, stone vase production and masonry, it can be suggested that the available know-how was applied to develop this practice for the purpose of shaping stone (apart from cutting mortises) in order to meet the new needs of Mycenaean monumental architecture and sculpture. From a technological point of view then, we do not need to see foreign, namely Hittite, influence on the use of drilling in Mycenaean masonry and sculpture during the palatial period (Blackwell 2014; this volume). Given the extended exchange networks of materials and techniques in the 2nd millennium BC (Procopiou 2006; Brysbaert 2008; Morero & Prévalet 2015) and the contacts (albeit indirect) between the Minoans and the Hittites (Georgakopoulos 2013, with bibliography), it is reasonable to consider that tubular drilling and sawing devices and related techniques constituted common technological practices throughout the Eastern Mediterranean by the 14th c. BC. In an attempt to differentiate between these techniques, it could be noted that drilling in Hittite architecture and sculpture seems to have been used – on a large scale indeed – for creating functional elements (mortises, eyes' sockets, mouths serving as fountains) (Seeher 2005: 23-31; Blackwell 2014: 477-480) rather than for shaping (contours), for which percussion (with stone tools) seems to have been preferred (see above). The aligned drillings tracing the contour of the lions at the Lions Gate at Mycenae in fact recall the aligned drillings on the Minoan blocks (Ayia Triada) or the successive ('honeycombing') drillings on the Mycenaean stone vases of the Late Helladic IIIA-B1 (*ca.* 1390-1250 BC) (see above, p. 247).

Specific materials: the case of emery as potential marker of technological traditions and transfers

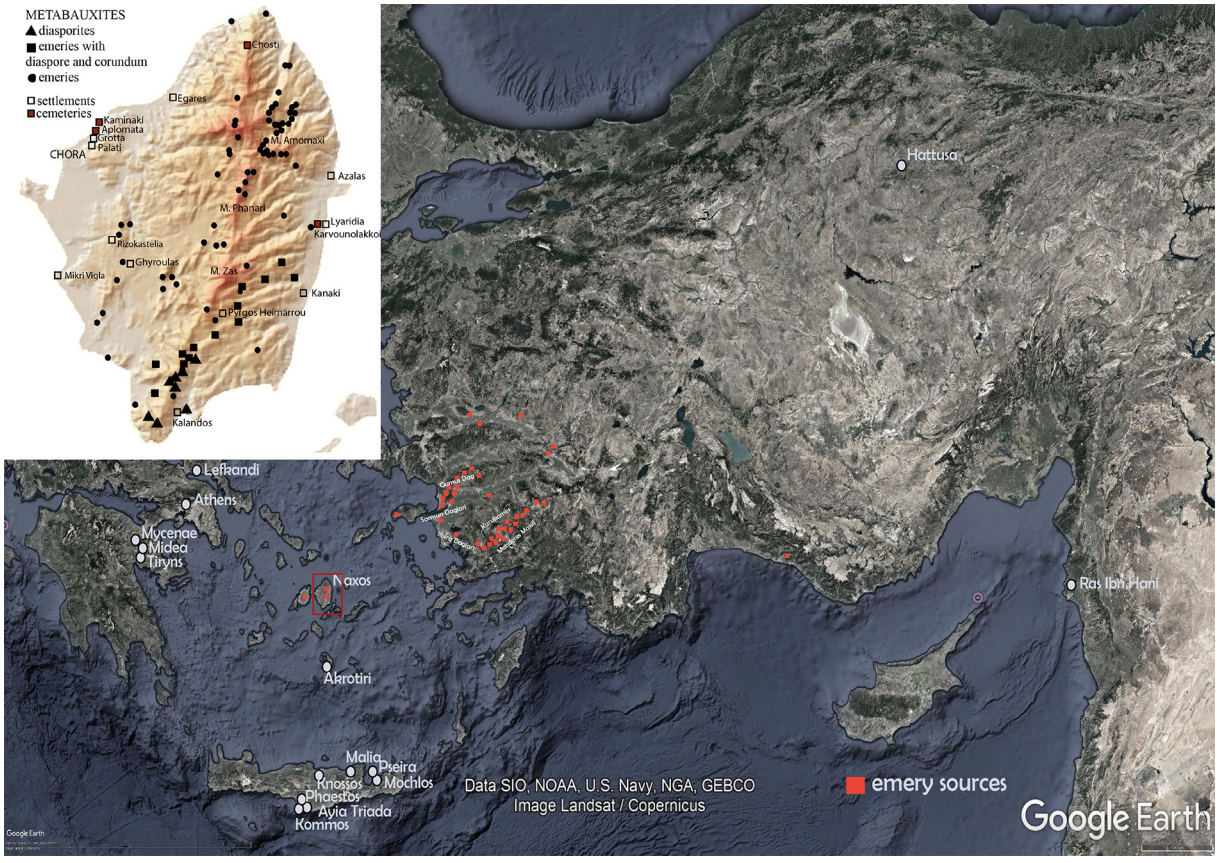

FIG. 9.6 MAP OF THE EMERY SOURCES IN THE EASTERN MEDITERRANEAN (AFTER FEENSTRA 1985; YALÇIN 1987; ÖNAY 1949) AND THE MAJOR SITES MENTIONED IN THE TEXT. DETAIL: EMERY SOURCES AND SITES OF THE MYCENAEAN PERIOD AT NAXOS, CYCLADES

Emery is an abrasive stone *par excellence* and can be related to specific techniques and practices including stoneworking. It is a metamorphosed bauxite (metabauxite) owing its abrasive properties to its main constituent, corundum, the hardest mineral after diamond. Depending on the degree of metamorphism, emery presents different mineralogical compositions and hence different physical and mechanical properties. There are more than thirty secondary constituents besides corundum, the most important being iron oxides and micas. In the Eastern Mediterranean, extended metabauxite sources exist in Greece (mainly the island of Naxos, with more limited sources at Paros, Ios, Sikinos, Herakleia and Samos) and in Western Turkey (mainly at the Menderes Massif and along the Gediz river) (**Fig. 9.6**) (for a detailed presentation with bibliography, see Boleti 2017: 72-76).

Metabauxites seem to have been used in the Aegean almost uninterruptedly from the Late Neolithic and the Bronze Age to Classical antiquity and even the Medieval and Modern periods in different forms (celts, pounders, polishing tools, whetstones, abrasive powder) and crafts. Interdisciplinary research based on techno-morphological and functional analyses of an archaeological corpus including raw material, waste and tools issued from sites in Greece, Turkey and Syria, has made it possible to outline different patterns of use for the Late Neolithic and the Bronze Age periods (*ca.* 5300-1070 BC) (Boleti 2017). These patterns show a strong connection between the different types of metabauxites, their mechanical properties and their exploitation. More precisely, emery with a compact texture containing mainly corundum and iron oxides was used for percussion (pounders), while emery with a bedded texture composed of large percentages of corundum and micas was used for abrasion (polishing tools and whetstones). These patterns of use also show significant chronological and geo-cultural variations. Emery percussion tools seem to reflect an extended, diachronic use from Neolithic to modern times. This is especially the case at Naxos, the main emery source in the Aegean. The preponderance of polishing tools, whetstones and abrasive powders, on the other hand, among the emery finds in contexts distant from the source areas, suggests that there was a high demand for this type of emery stone tools, especially in Neopalatial and Final Palatial Crete (*ca.* 1700-1360 BC). The presence of emery and corundum sources in specific regions of the Eastern Mediterranean and its use in different crafts and techniques make it thus a potentially strong indication of technological traditions and transfers.

Percussion

On the island of Naxos, abundant surface finds, as well as contextual evidence mainly dated to the Early Bronze Age (3rd millennium BC), show that emery was widely used for percussion. Two pounders from the Bountali plot could have been used for stoneworking, a hypothesis further corroborated by the immediate proximity to the marble quarry of Melanes (Boleti 2017: 120). The latest research at Panormos showed that an Early Bronze Age settlement existed on the terrace below the acropolis of Korphari ton Amygdalion (Angelopoulou 2014). The discovery of emery pounders on the surface of the terrace below the acropolis, alongside with limestone debris (Devetzi 2014), suggests that this type of emery tools was used in the construction of the settlement, although it cannot be excluded that they were used in more recent periods (Boleti 2017: 122, 222). Despite the importance of such finds, the clearest evidence for stone dressing with stone pounders in the Aegean seems to come from early Late Bronze Age Akrotiri. The probable presence of emery percussion tools among the unpublished material from this site (Boleti 2017: 131), could be related to stoneworking and the use of imported emery tools. Considering, however, the present state of research, evidence for Bronze Age emery percussive tools outside Naxos remains rather limited. Only four emery (and diasporite) percussive (multi-functional) tools are known from the sites of Pseira, Mochlos and Kommos on Crete (Boleti 2017). A few more tools are mentioned in the publications from Late Helladic IIIB2 (*ca.* 1250-1190 BC) Mycenae (Iakovidis 2013: 233) and Late Helladic IIIC (*ca.* 1190-1070 BC) Lefkandi (Evely 2006: 79-80, 268). Evidence in favor of a specialized use of emery pounders in masonry hence remains very limited, but can be reasonably assumed on the basis of related contexts (Boleti 2017: 222-223) and cross-craft interaction, as attested in other fields of stoneworking (stone seal and vase production) in the Bronze Age Aegean.

Abrasion

There is more substantial evidence for the use of emery as an abrasive. The use of emery sand or powder for cutting stone with saws and drills has been suggested since the beginnings of archaeological research in Egypt and the Aegean. As soon as sawing and drilling practices were attested in Egypt, the use of abrasives with copper/bronze blades was favored, especially for cutting hard stones in the Early Dynastic period (*ca.* 3000-2686 BC) and the Old Kingdom (*ca.* 2686-2125 BC). The use of emery was first suggested by Petrie (1884; 1909; 1917), though in the form of fixed pointed pieces. The hypothesis of emery use was adopted by other scholars on the basis of the stone's abrasiveness and hardness (for a synthesis see Stocks 2003: 107-109; Boleti 2017: 33-35, with bibliography), but was strongly challenged by Lucas and Harris (1962: 72-74, 261), and more recently by Stocks (2003: 103-138). The arguments presented by Lucas and Harris were the absence of emery sources in Egypt, as well as of any archaeological evidence (at the time they conducted their study) pointing to exploitation of emery sources in Egypt and the Aegean in the 3rd millennium BC, while quartz sand, also efficient for cutting stone, was abundant in the Egyptian desert, costless and had been found in a stone vase maker's workshop dating to the Old Kingdom (*ca.* 2686-2125 BC). The main arguments of Lucas and Harris were adopted by Stocks (2003: 103-108) and further reinforced by his experiments, which demonstrated the efficiency of quartz sand. Stocks (2013: 126-8) also challenged the use-wear traces analyses by Gorelick and Gwinnett who, based on experiments, argued for the use of emery, which "was to the ancient lapidary what tin was to Bronze Age metallurgy" and revolutionized the hard stones' industry (Heimpel *et alii* 1988: 210; for a synthesis of their numerous experimentations see Boleti 2017: 57-61). Kenoyer, who also conducted drilling experiments, asserts that it is possible to differentiate between abrasives (quartz, emery, diamond) using a higher resolution imaging than that used by Gorelick and Gwinnett for use-wear analyses and identifies the use of emery with solid drill bits for bead making in Middle Bronze Age and Late Bronze Age Troy (Ludvik *et alii* 2015). Despite all the above experiments, to which the work of Seeher (2005) and Morero (2017) should be added, it remains a complicated task to identify the use of abrasives and further distinguish between corundum/emery and other abrasives based solely on use-wear traces, *i.e.* the type of striations produced by drilling.

The use of emery in Egypt from the middle of the 4th millennium BC onwards could indeed account for the large-scale production of hard stone vases. However, the sources of corundum known in the region of Hafafit in Egypt were too limited to meet the needs of a local exploitation. Corundum appears there in pegmatite veins of small scale (El Shazly *et alii* 1975a; 1975b), and no traces of ancient exploitation have been observed during the most recent survey in the region (Harrell & Brown 2002). The metabauxite sources in the Aegean including Western Anatolia were known and exploited during the Final Neolithic and the Early Bronze Age (5th-3rd millennium BC), but we possess no concrete archaeological evidence for the patterns of use assumed for Egypt, namely drill bits or abrasive powder for drills and saws. A few emery blocks are reported among the surface finds at the marble workshop at Kulaksizlar (mid-5th millennium BC), but these do not seem to have played a role in the drilling processes of the marble pointed beakers produced there (Takaoglu 2001: 86).

Literary evidence also prompts us to seek an early use of emery as an abrasive in the Eastern Mediterranean. The identification with emery of the *šammum* stone mentioned in the Mesopotamian myth of *Lugal.e* seems legitimate, based on the characteristics attributed to it, namely its abrasive property and its use necessitating or resulting in its pulverization. This would attest the use of emery as early as the 3rd millennium BC in Mesopotamia. The piercing of cornelian, a particularly hard stone, is the most precise mention of stoneworking involving emery, which also implies its use in drilling processes (Michel 1996). Mentions of the *šammum* stone in several other Mesopotamian and Near Eastern texts – the most interesting in the archives of Mari – confirm that it was known and used at least since the beginning of the 2nd millennium BC (Heimpel *et alii* 1988; Michel 1996; for a synthesis Boleti 2017: 42-46). In addition to the Mesopotamian sources alluding to a long tradition of emery/corundum use especially in conjunction with cornelian stone as early as the 3rd millennium BC, the annals of Amenmenhat II also attest to the use of emery abrasives in the 2nd millennium BC. According to Altenmüller and Moussa (1991, see also Grimal 2005), the annals inscribed in the Temple of Ptah in Memphis during the reign of the Pharaoh Amenmenhat II (*ca.* the beginning of 19th c. BC) make clear reference to emery (*jsmrw*) imports. More precisely, the annals mention an expedition in Lebanon (Altenmüller & Moussa 1991: 14) or in Syria (Grimal 2005: 558) aiming at acquiring supplies in metals and minerals, including considerable quantities

of emery powder – 226 kg (Altenmüller & Moussa 1991: 47-48) or 453 kg (Grimal 2005: 558). The same annals mention 83 emery blocks delivered to the pharaonic administration for distribution. Since no emery or corundum sources are known in Syria (on possible occurrences see Boleti 2017: 73, 153) and Lebanon, it is suggested that emery was transported to these regions and was then further distributed, a hypothesis that fits well with the picture of emerging merchant cities in Northern Syria during this period (Grimal 2005: 558). Such a transaction could very well fit with the exchange networks developed between Mesopotamia, Egypt and the Mediterranean through the Levantine 'corridor'. Given the above evidence and the long time-span covered by the Bronze Age in the Eastern Mediterranean, we may consider the existence of alternating and possibly overlapping networks of diffusion of emery/corundum from the Aegean (islands and Western Anatolia), lasting from as early as the 4th-3rd millennium BC down to the end of the Late Bronze Age (*ca.* 12th c. BC) with several possible interruptions. Evans (1921: 14, 55) shared Petrie's conviction that Naxian emery was exported along with Melian obsidian to Egypt from the Neolithic period onwards, and Heimpel *et alii* (1988: 200) suggest an Aegean provenance for emery discovered and referred to in Mesopotamian archeological and literary contexts.

In contrast with the aforementioned contexts for which we have chiefly literary evidence and use-wear traces analyses, strong archaeological evidence illustrates the wide use of emery/corundum powder in the Aegean from the end of the Middle Bronze Age and during the Late Bronze Age, mostly in Minoan contexts (Neopalatial and Final Palatial periods, *ca.* 1700-1360 BC)[6]. The block from Ayia Triada on Crete is an interesting find, because it does not only illustrate the use of drilling practices in the framework of masonry techniques, but also is one of the cases where emery has been identified in the form of abrasive powder used with a tubular drill. More precisely, XRD analysis of the paste/sediment remaining in the grooves showed that it contained corundum along with calcite and little quantities of quartz (Lazzarini 2001: 576-579). Warren (1969: 160) mentions emery powder identified through analysis on four cores bore out of banded tufa, breccia, gabbro and serpentine found in Late Minoan IB-II/IIIA contexts in Knossos (*ca.* 1510-1330 BC). He also mentions traces of emery powder on a waste fragment of an Egyptian alabaster from a Late Minoan IA level (*ca.* 1600-1515 BC) at the same site. Heimpel *et alii* mention that emery powder, identified through XRD analysis, was found in the perforation of a Minoan (MM IIIB-LM I, *ca.* 1640-1430 BC) quartz seal coming most probably from the Gypsades hill at Knossos (Heimpel *et alii* 1988: 208; Gorelick & Gwinnett 1992). The fact that the use of emery was not limited to the drilling of hard stones demonstrates its generalized character. Morero's (2016: 151) experiments have shown that emery powder does not necessarily accelerate the drilling of soft stones (serpentine) and stones of medium hardness (marble), although the abrasive grains are used out much more slowly and there is less need to supply additional abrasive. Evidence for emery powder on bore-cores mainly comes from palatial contexts, and it seems that artisans having access to emery supplies chose to make a wider use of it. Raw pieces and tools made of especially abrasive types of emery that could also be easily ground into powder should be added to the above evidence (Boleti 2017: 100-101). Unfortunately, none of the emery finds reported from Protopalatial Malia (Heimpel *et alii* 1988: 204; Boleti 2017: 132, n. 7) has been studied in detail. Thus, by the Middle Bronze Age, the Minoans were fully acquainted with and appreciated the abrasive properties of emery and made large-scale use of it in the framework of techniques already mastered for a long time, especially drilling.

In Mainland Greece, the use of emery with drills and saws is also suggested for the Mycenaean palatial period in the case of the Lion Gate relief at Mycenae, although this awaits confirmation (Blackwell 2011; 2014). The already mentioned presence of emery at Tiryns, identified by Petrie in the late 19th century (Dörpfeld 1885: 247-248), should also be added to the above, although the exact pattern of use is difficult to reconstruct. However, evidence for the use of emery powder also comes from very different contexts related mostly to metal-working: emery powder is reported as a filling substance for Mycenaean gold rings (Younger 1981: 32) and gold relief beads (*ca.* 15th-14th c. BC, Konstantinidi-Syvridi *et alii* 2014: 12-13). If we add the mentions of emery percussive tools (see above), the available evidence points here again to a generalized use of emery. The know-how related to the use of emery powder as an abrasive was preserved and transmitted along with relevant technology

6 Available archaeological evidence outside the Aegean is very limited. Analyses revealed the presence of corundum in the debris of drilling on a piece of hard limestone from the Great Aten Temple at Amarna (*ca.* 14th c. BC) (Serotta & Carò 2014). The more than 500 natural blocks of almost pure corundum weighing 300 kg found at the Palace of Ras Ibn Hani in Syria (beginning of the 12th c. BC), most probably linked with cornelian beads production, are an exceptional find (Bouni *et alii* 1988). In this case a corundum source outside the Eastern Mediterranean may be sought (Boleti 2017: 243-245).

throughout the successive Minoan and the Mycenaean eras. As Evely (1993: 213) states "The kit for the mason would be as much as that for the stone-vase worker" and would therefore include emery tools and abrasives.

Emery exploitation on Naxos seems to continue throughout the Bronze Age, and the extended emery sources on the island – the largest supplying sources amongst the Aegean islands – must have supplied Crete, the other Aegean islands and Mainland Greece during the Minoan and Mycenaean periods (Boleti 2017). Strong Mycenaean presence on Naxos, as suggested by the flourishing settlement of Grotta, a small-scale tholos tomb in the north-eastern part of the island (Chosti) and other finds in the region of emery sources (Azalas, Lyaridia and Kalandos; Philaniotou 2006: 37-40), could be especially related to the exploitation of emery sources on the island. Watrous (1992: 81) interestingly mentions the presence of three Naxian pithoi at Late Minoan IIIA2-B (*ca.* 1360-1200 BC) Kommos, that could also hint to a Naxian provenance for the emery tools coming from the same layers at the site. On the contrary, no concrete archaeological evidence is available for the exploitation of the extended emery sources in Western Anatolia (Seeher 2005: 22-23; 2008: 12), although these include loose outcrops near the surface relatively easy to extract (Boleti 2017: 153). The use of emery for stoneworking has not been proven yet in Hittite contexts either, although it is reasonably assumed based on its higher efficiency for drilling hard stones as compared with quartz sand as confirmed by Seeher's experiments (2005: 22-23). Emery, most probably used with drills and saws in Mycenaean architecture and sculpture (*e.g.* at Tiryns and Mycenae, see above, xx), can thus further corroborate a local tradition perpetuating a Minoan 'legacy' during the palatial period, at least as far as the tubular drill is concerned. In other words, a consolidated know-how (hard stones drilling/sawing) as well as necessary materials (emery) were available and could be applied on a large-scale in the framework of monumental architecture and sculpture. Even if these constructions were assumed to follow a plan of Hittite conception, technical/practical issues of execution could have been locally addressed, and specialized craftsmen could also be recruited locally.

Concluding remarks and perspectives

The present state of research and related methodological issues prompt us to suggest a considerably wider use of stone tools and related techniques in stone masonry than is generally accepted. The evidence also highlights their general use in a metal-using society, an issue that has preoccupied archaeologists (see for example Karimali 2010). There are good reasons to assume that drilling with mineral abrasives in stone masonry represents a more long-standing tradition in the Aegean than previously thought, rooted in Protopalatial Crete and perpetuated until the Mycenaean palatial period. Evidence (tubular drilling in seal cutting, stone vase production, stone masonry and sculpture and abrasives used in these practices) presented here also illustrates cross-craft interactions and provides a basis for further assessing cross-cultural influences. From this perspective, we may argue for Egyptian influence when drilling practices were first applied in masonry (Protopalatial Crete) and for more consolidated, though flexible, traditions concerning these same techniques in the Late Bronze Age (Mycenaean palatial period in Mainland Greece). Percussive stone tools were most likely an integral component of the mason's tool kit and can also point to cultural affinities or differences in the Eastern Mediterranean.

Despite several technical studies and experiments that demonstrate the use and efficiency of stone tools and materials for shaping sculptures, masonry blocks, vases and other elements in stone, there is still much room to improve our knowledge of related patterns of use. All experiments reviewed here focus on specific aspects (materials, techniques, contexts) and are, in this sense, partial. A more holistic and interdisciplinary approach based on material sourcing and characterization, large-scale experiments, multi-scale use-wear traces analyses and more specific oriented (ethno)archaeological studies is necessary in that direction. Such an approach will aim to provide a sufficiently large corpus of stone tools and corresponding marks based on the study of architectural remains and on experiments and will allow for detailed comparisons. As a result, stone tools that remain elusive in the archaeological record will be successfully tracked down and techniques and practices in which they were involved will be better understood.

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