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NOESIS
ΚΕΝΤΡΟ ΔΙΑΔΟΣΗΣ ΕΠΙΣΤΗΜΩΝ & ΜΟΥΣΕΙΟ ΤΕΧΝΟΛΟΓΙΑΣ

Το Διοικητικό Συμβούλιο της Εταιρείας Διερεύνησης της Αρχαιοελληνικής και Βυζαντινής Τεχνολογίας (ΕΔΑΒυΤ) ανέλαβε την ανάρτηση στην ιστοσελίδα της (www.edabyt.gr), σε ψηφιακή μορφή, των εργασιών του 3ου Διεθνούς Συνεδρίου Αρχαιοελληνικής και Βυζαντινής Τεχνολογίας (Αθήνα 19-21 Νοεμβρίου 2024).

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The Board of Directors of the Association for Research on Ancient Greek and Byzantine Technology (EDAByT) undertook the posting on its website (www.edabyt.gr) of the papers presented at the 3rd International Conference on Ancient Greek and Byzantine Technology (Athens, November 19-21, 2024).

The papers had been subject to reviews and comments by the Scientific Committee. Additionally, further observations and comments were made during the discussion that followed their oral presentation at the Conference.

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THE TECHNIQUES OF MARBLE EXTRACTION IN THE ANCIENT QUARRIES OF THASSOS

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Abstract. The identification of numerous ancient marble quarries on Thassos Island and the meticulous observation of the different traces in the quarries allow us to restituate the marble exploitation chain in its entirety. The extraction remains led to differentiating eleven specific techniques of extraction corresponding to determinated periods of exploitation, from the archaic to the early Christian time; and three others used throughout Antiquity. The oldest technique of extraction is the rock breaking [1], (without real remains on the quarry front itself) is attested by the stone cuttings debris nearby the extraction place. We are able to recognize — the opai technique [2], of which the traces are the square holes for square headed wedges, with their variant volume I and A; — the technique of the carved channel [3]; — the Parian technique [4], with the aligned rectangular wedge holes and chisel points marks between them; — the technique of «encoignure» [5], where at the bottom of the sandpile shaped hole, was carved one hole for a wedge, rectangular or an A or a T shaped hole; — the «emboîtures» technique [6], where the aligned holes for rectangular headed wedges are distinguishable by their various shapes; — the technique of the «mega-emboiture» [7], where the hudge holes attest to the use of special wedges; — the technique of the «enjarrots» [8], recognizable by the carved channel that shows at its bottom, many rectangular holes for wedges, regular spaced; — the technique of the «enjarrot composite» [9] ; — the «rainure» technique [10], where grooves and special thin wedges are used; and — the «enfonçures» technique [11], confirmed by the aligned chisel holes. The techniques of extraction of monolith column shafts **[**12**]**, cylinder shaped objects (big drums or small milllstones) **[**13**]**, and sculptures **[**14**]**, are the same during the Antiquity. In reason the extraction of these three artefact types does not often leave traces of the used tools, it is not always possible to attribute the exploitation to a precise period. On Thasos, no traces of extraction using the saw [15] have been identified in the quarries. The reference will be those left at Euboia. But the sawed blocks on Thasos explain well the technique.

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Keywords: Thassos, Quarrying, Extraction techniques, Tools.

1 Introduction

On Thasos, the ancient quarries are numerous, and very different from each other, either because of their locations and "morphologies" following the extractions, or because their current aspects correspond to their abandonment state, which turns out not to be synchronous. In addition, some quarries have been reopened, damaging the old working faces, or even making them disappear completely. This phenomenon does not only exist in modern times, but already in Antiquity, as certain quarries were exploited several times, in different centuries.

All the quarries on Thasos are open-cast. It seems that the marble to be extracted was almost on the surface, and that the overdraft was not too significant, if not non-existent [3]. The exploitation of marble has therefore been facilitated since ancient times. The exploitations are on the surface, in pits, in trenches or in a U shape, or they had even attacked the hill head-on [4]; or were reduced to the volume of a finger quarry [5]. As for the seaside quarries, due to the rise of the sea level, we have erroneous images by perceiving "fringes" of quarries, as in *Saliara-Vathy* or even *Spastiras, Skydia*, etc., whereas the exploitations were much more extensive and these areas are now underwater, as evidenced by the C quarry in the *Aliki* peninsula.

Once a quarry has been identified, the meticulous observation of the traces left on the working faces and the quarry floors is necessary in order to distinguish the different extraction techniques, to associate them with a period of exploitation and also to record the extraction processes that remain invariable over time.

Neither the other marks [6], which do not directly relate to extraction, or the remains of the extracted products [7], nor the human occupation traces [8], will be discussed here, due to lack of space. Obviously, the "quarry" also called the "extraction site"or the "exploitation sector", is only a part of the quarry eco-system.

2. The techniques

Meticulous observation of the traces on the working faces and on the extracted blocks allowed us to distinguish them, to recognize marks due to different methods of extraction, and to attribute them to extraction techniques.

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[3] It could also be a reason that motivated the Parians to colonize Thasos. Their quarries are mostly underground.

[4] The front can reach over 30m high.

[5] Finger quarries are isolated sections where a single product is extracted. Mostly *kouroi*, as those in Naxos during the archaic period.

[6] Other marks can be recognized, which contribuate to the exploitation organization. For examples the cavities: *gourna*, witness of tools reparation workshop nearby the quarry-front; cavities for posts, capstans, hoasting-machines, of which the restitutions help us to / get // figure out / the transport of the artefacts from the extracted place to the worshop, to the storage place, until they leave the exploitations. Glyptographic marks also contribute fto understanding the ecosystem.

[7] Analyzing the abandoned artefacts, types, stages of work….

[8] For example the specific areas, such as sculptor workshops, storage platforms, and also the settlements, the sanctuaries etc.

Although a new technique does not replace the previous one overnight, we can see that the use of these techniques evolved over time, and we can also point to techniques that lasted throughout Antiquity.

2.1 The "spalling" technique ("*délitage*")

Rock spalling must also be considered a technique, even if it leaves no trace on rock surfaces. It uses cracks and imperfections in the bedrock to recover blocks (fig. 1).
Obviously, it is not possible to differentiate between a block which spalled due to weathering and a block broken off in layer and detached by human action. We therefore have no record of this technique being used.

The tool used was a lever bar, which was pushed into the crack to enlarge it until part of the bedrock broke in a more or less thick slab.

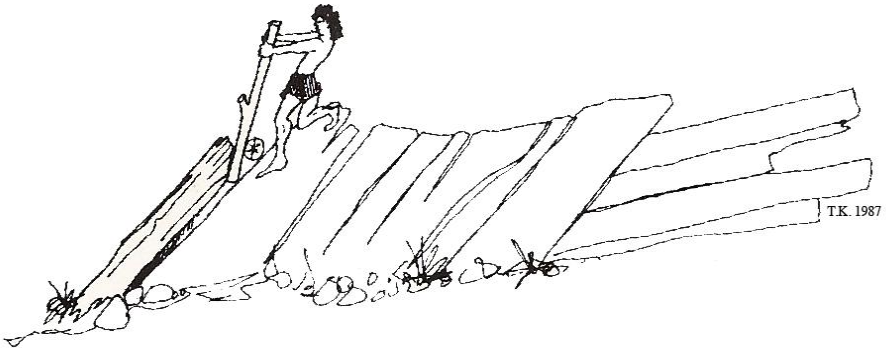

Fig. 1. Rock spalling technique (T. Koželj, 1987).

In the vicinity of the Neolithic settlement of *Kastri* and in the neighborhood of some necropolis (*Vrisoudes, Larnaki, Kentria, Tsiganadika*), areas covered in marble chips and debris attest to the work of splitting and the transformation of the extracted marble into slabs, building blocks and refined sculptures (for example at *Skala Sotiros* [9]). These places would be the oldest cutting workshops and therefore, the oldest quarries on the island, as indicated by Haido Koukouli-Chryssantaki:

«*οι εξι θεσείς των λατομείων, που έχουν εντοπίσθει στην μαρμαρόφορα περιοχη του λοφου Τσιγαναδικα, πρεπει να αποτέλουν τα αρχαιότερα λατομεία στην Θασο*» [10].

2.2 The "opai" extraction technique[11] or the technique using square headed wedges.

Although on the surface, the " *οπαί* " are wedge's sockets with a square section, they are differentiated by their volume:
- opai I: socket, with a narrow profile, close to a parallelepiped shape, resembling an "I",
- opai A: wedge socket, with a stocky truncated pyramidal volume, comparable to "A".

[9] (Koukouli-Chrysanthaki, 1987, 389-431, sp. 396).

[10] (Koukouli-Chrysanthaki, 1992, 692-697, sp. 684). Traduction M.W-K.: «The six quarries, located in the marble area of the hill Tsiganadika, must be the oldest quarries in Thasos ».

[11] (Kozelj, Wurch-Kozelj, 2023, 421-428). *Οπαί / οπές* [modern greek]: hole, orifice, often used to define a wedge-socket. For us, the «*Οπαί*» are wedge-sockets, with a square section, which received a square head wedge. We designed the technique from memory based on the profil of the half wedge-socket, I for the narrow profil, and A for the stocky one.

We also noted a correlation between the spacings and the type of socket: widely spaced sockets are of the opai I type, while those relatively close together are of the opai A type.
These disparities or particularities appear to correspond to the two methods of the same extraction technique using square-headed wedges. We observed that no channel limits the perimeter of a block or a mass to be extracted; the face on which the opai sockets are located turns out to be either free or between natural faults in the rock. This technique uses imperfections and defects in the bedrock to extract the desired block (fig. 2).

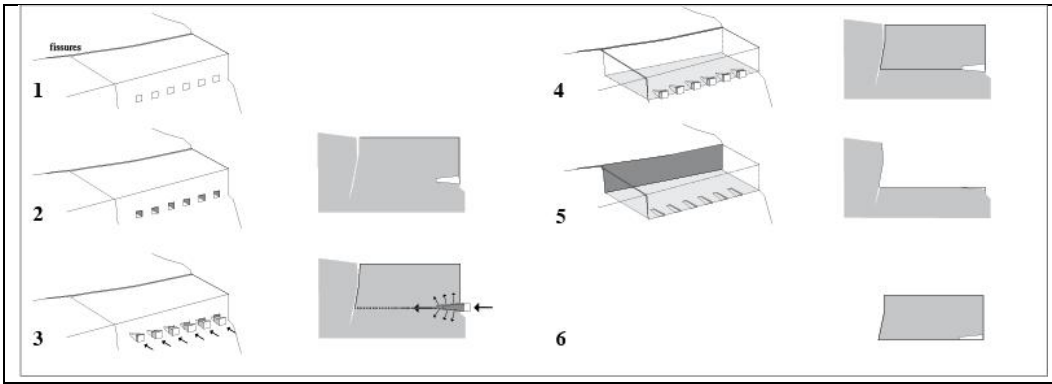

Fig 2. Opai extraction technique, schema (M.W-K).

Traces of opai I are visible on working faces in *Saliara* 3, in *Thymonia*, in *Agios Ioannis Loukas* as well as on blocks. A trace of opai, which is visible on the front-face of a block from the circular tower in *Ag. Ioannis Loukas*, was therefore not used to extract this block in particular and is evidence of an oldest ancient quarry-front [12]. The traces used to extract the blocks are generally half-opai, as evidenced by certain blocks belonging to the tower of *Thymonia*, or even to the terrace of the sanctuaries at *Aliki* (fig. 3ab).

Fig. 3a. *Aliki*. Detail of two opai I-sockets. (The left one is more weathered).

Fig 3b. Opai I profil. (The right one is better preserved).

Traces of opai A are visible on a quarrying face at *Saliara* 7, where serial extraction is evidenced by these parallel alignments of opai A. A block bearing half-opai A is another testament // record.

[12] Another explanation is that this quarry face was the result of a previous exploitation using the opai I technique and was once again used to extract this block and the other ones of the tower; or this is a stage in the progress of the quarrying, which would date the construction of the tower and the use the opai I to the same period.

To complete our analysis, iron wedges corresponding to the opai I and A wedge-sockets were identified. During the excavation of the Gate of Silenus area in Thasos town, Y. Grandjean[13] recognized a “kind of wedge”, n. 134 (fig. 4). Despite its poor state of conservation, it is comparable to a wedge used in the opai I technique.
No wedge with a square head and a truncated pyramid shape has been dicoverd on Thasos to this day. However, at the ancient *Anô Latomeia Kourtzi* quarry in Mytlilène [14], a wedge of this type was found among other quarrymen’s tools [15], and is similar to the sought-after tool (fig. 5).

Fig. 4. Gate of Silenus area. Wedge N.134. (photo: Ph. Collet, EFA)

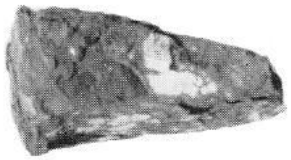

Fig. 5. Detail of a wedge type opai A, in Mytilini. (BCH 86, 1962, 879 fig. 4).

In conclusion, should we see an evolution in the opai technique? Are the two methods contemporary or is one older than the other? There is no real evidence to confirm this. There is no doubt that the circular towers, *Thymonia, Archangelou, Agios Ioannis Loukas,* etc. and the terrace of the Aliki sanctuaries date from the early Archaic period.
The elements identified concerning this “opai” technique indicate that it was in use before the arrival of the Parians on the island. It remains to be seen whether it is a “local” technique, invented by the natives, or an “imported” technique used by the first migrants to the island. From a single “opai A-wedge“ identified in Mytilene and these few traces identified on Thasos, it is still risky to form a hypothesis of either importation of this technique or diffusion of a technique already used on Thasos.

2.3. The digging of channels

In the absence of faults or cracks in the working face to delimit the dimensions of a block to be extracted, channels had to be dug. This is not a technique in itself, but a basic method of determining the volume to be extracted using a technique. They are easy to spot, on the three sides of the blocks that are still not detached or surrounding block negatives. The channels have several shapes, — in profile: with upright worked sides and a flat bottom (fig. 6), or with oblique sides forming different V shapes; and — in plan: rectilinear, curved or circular. Their dimensions are more or less “proportional” to the dimensions of the blocks, knowing that the upper width of the channel is at least 0.15m, corresponding to the minimum space for a quarryman to be able to work there while digging the channel in the desired depth, depending

[13] (Grandjean, 1988, n. 134). EFA photo n. R2334-006. We have not seen the wedge.
[14] The ancient quarry of *Anô Latomeia Kourtzi* is located between Pagani and Outza. (Daux, 1962, 876).
[15] (Daux, 1962, 879 fig. 4). This set of tools consists of a pick, a wedge «opai A» and a compass. No measurements are given, nor any dating of the quarry. Onlly unfinished column drums are mentionned.

on the height of the block. The width sometimes becomes smaller as the depth increases, leaving traces of stenosis on the sides (see example, fig. 29).

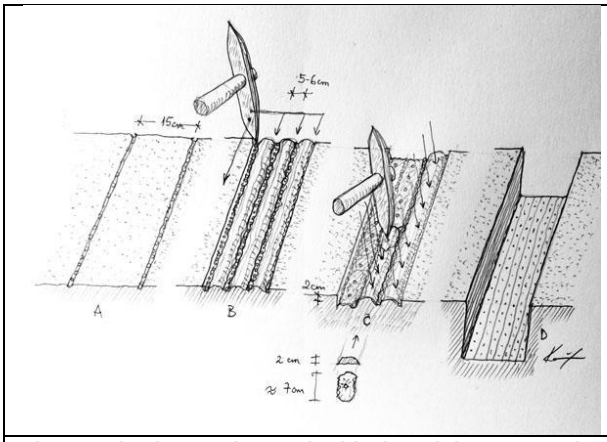

Fig. 6. Digging a channel with the pick: traces. (Drawing: T.K.)

The depth of the channel is often greater than the height of the desired block. Its bottom is almost always “lower” than the alignment of the sockets, often by 0.05m. This detail can be explained technically: under the impact effects, the splitting plane is created, and it is the space of the dug channel which will “stop” the propagation of the strike waves and limit the splitting plane to the extent of the block that we see after extraction, in the form of a negative (fig. 7). Many quarrying techniques use channel digging.

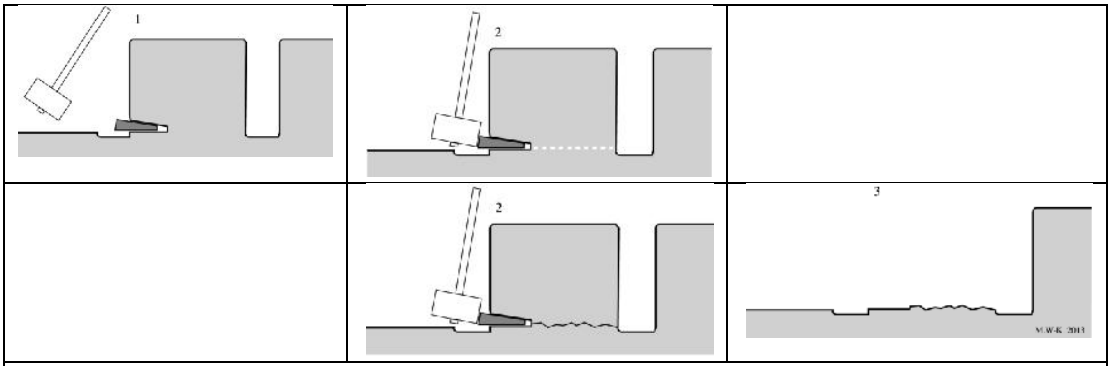

Fig. 7. Detachment of the block under the effect of strikes on the wedges.
(Drawing: M.W-K.)

In conclusion, the technique of digging channels is invariably the same. Therefore, it is not possible to suggest the time period of the quarrying based only on the channel marks. However, when traces are visible on the fourth side of the block or on the negative, these will make it possible to recognize the technique used and allow us to estimate the extraction period.

2.4. The «Parian» technique of extraction

The extraction technique used by the Parians left very specific traces: alignments of rectangular wedge-sockets where the intemidiate space is occupied by a series of impacts due to the chisel-point (the number of which is most often odd 3, 5, 7; and up to 30 on Paros). We noted on several occasions that a crack had been used to delimit sidely the block to be extracted, but most of the time, this technique resorts to the digging of channels.

To extract a block, the work takes place in several stages (fig. 8), with the appropriate tools:

1. The outline of the block is engraved on the surface of the marble.
2. The channel is dug using the pick, the point and the mallet, delimiting the three sides of the future block, and on the front face, several rectangular sockets are dug with the point and the mallet.
3. The striking effect on wedges with a rectangular head embedded in the sockets causes waves to propagate and determines the split plane in the bedrock.
4. Hammering the points using the mallet, following a horizontal line between the sockets, contributes to the rupture of the rock (hence the impacts and holes, the depth of which is a result of the number of strikes necessary).
5. The repetition of strikes on the wedges and points allows
6. the detachment of the block, following a flat surface, which determines
7. the negative of the block and
8. the block with the desired dimensions.

These traces can be recognized in the quarries of Paros (*Marathi, Lakkoi*), exploited in the 7th c. BC; and in the quarries of Naxos (*Flairio* and *Melanes*), on Delos (quarry in the South-East of Kynth), in Euboea (*Karystos*), and on Thasos, where the most important concentration of traces is in *Aliki* (in the quarries A, at the tops of the partitions between the quarrying-sites B (fig. 9ab) and even at the southern tip of the peninsula (ahead of quarry C, fig. 9c), despite successive exploitations.

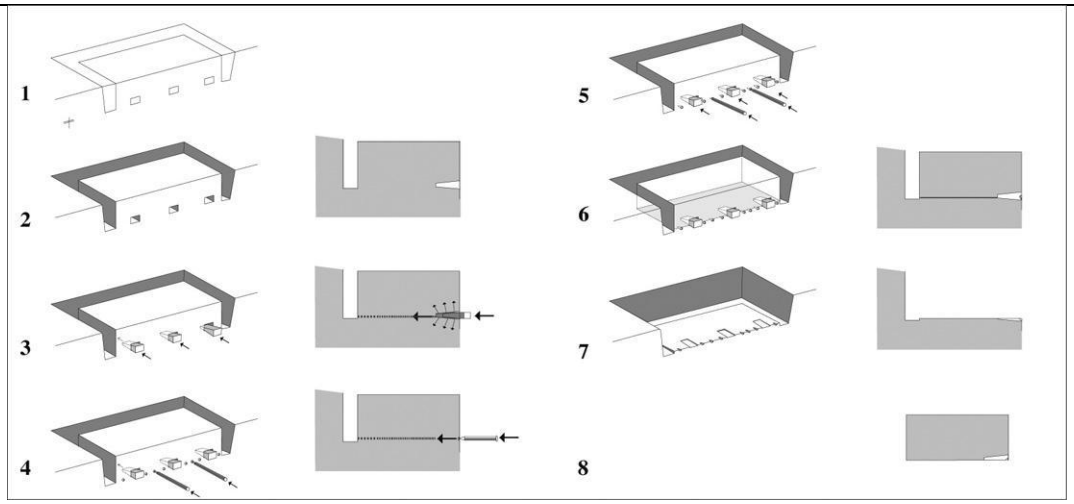

Fig. 8. Parian extraction technique, schemas.

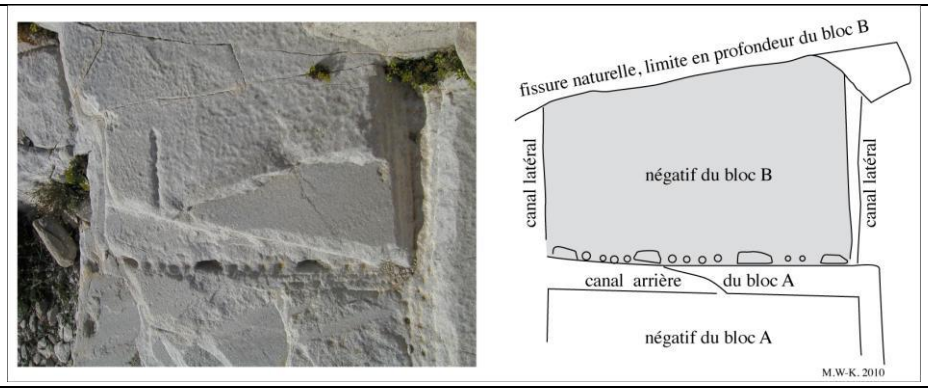

Fig. 9a. Thasos. *Aliki* B. Partition B5-B6. (photo, drawing: M.W-K.).

Fig. 9b. *Aliki*. Partition B10-B11. (photo : M.W-K.).

Fig. 9c. *Aliki*. South of the peninsula (photo: T.K.).

Other traces of the "Parian" technique are visible on working faces in *Thymonia* and *Agios Ioannis Loukas* (nearby the traces of opai, which indicate successive exploitations); in *Franko-Ekklisia*, in *Skydia*, in *Agia Eirini*, where block-negatives bear witness to this, but also in places where the extraction of the block remained unfinished and often where the marble is no longer of good enough quality. The isolated traces on a working face at *Fanari* 4 (below the lighthouse) and at *Saliara* 4 are the results of sectors abandoned by subsequent exploitation. But this technique was also used for the extraction (in sector 14) of the blocks necessary for the development of the ancient road from Artemision to the acropolis [16]. Several blocks also bear marks of successful extraction such as the one used in the terrace of the sanctuary at Aliki, or in the circular towers, [T83] at *Fkiaria*, and that at *Archangelou*.

The technique was also used to cut a smooth column shaft (without spline), the traces of which – an alignemnt of rectangular wedge-sockets and chisel-point holes in between- are visible on this left fragment [17]. A trace, which was not used for extraction, is recognizable on the rear of a block in Tower VI of the citywall of Thasos [18], and is evidence of a working face from a previous exploitation, that is earlier than 494-491 BC (date of construction of the citywall).

In conclusion, the traces are not only proof of the exploitation of marble by the Parians (or imposing their technique on the quarrymen), but are clues, which, combined with excavation data, allow us to reconsider and reinterpret the process of the "colonization" of Thasos by the Parians.

[16] (Kozelj, 1983, 718 fig. 1; 738, fig. 40; 742, fig. 42). Traduction: «… five similar notches [sockets], connected by a series of small holes made with a pick, is the oldest evidennce of the use of such a tehnique».

[17] Could this fragment of a smooth column, restituated diameter ± 0.60 m, belong to the colonnade of a "first sanctuary" ? Was it built earlier or is it contemporary with the small terrace? The hypothesis remains unprovable (for the moment), althrough J. Servais mentionned that «the sanctuary existed as early as 650 BC, and the small terrace has been built around circa 600 BC» (Servais, 1980, 27-28).

[18] (Grandjean, 2011, 429-446 and fig. 351 à 369). (Kozelj, Wurch-Kozelj, 2000, 417-426. See sp. 419 and fig. 4c).

2.5. The technique using the «*encoignures*»

The «encoignures» are cavities with a specific volume of sand heap, at the bottom of which rectangular wedge-sockets are dug (fig. 10). The technique using those cavities, isolated or grouped in a row, is used to extract very large blocks, or even rock masses.
The surface opening varies from 0.15 x 0.09m to 0.30 x 0.15m. The “sand heap” cavity is 0.06 to 0.12m deep and the bottom is a rectangle of 0.08 x 0.02m to 0.15 x 0.04m, which corresponds to the opening of the socket, 0.13 to 0.15m deep. Sometimes the section of the socket becomes smaller towards the bottom.

Particular wedges had to be forged expressly for this technique.

Numerous isolated traces or alignments of «encoignures» are recognizable on the working faces of the eastern quarries of Thasos, at *Fanari* 5, *Vathy* I, and on a block used as the first course in the “*Machmout* ” Tower near Liménaria.

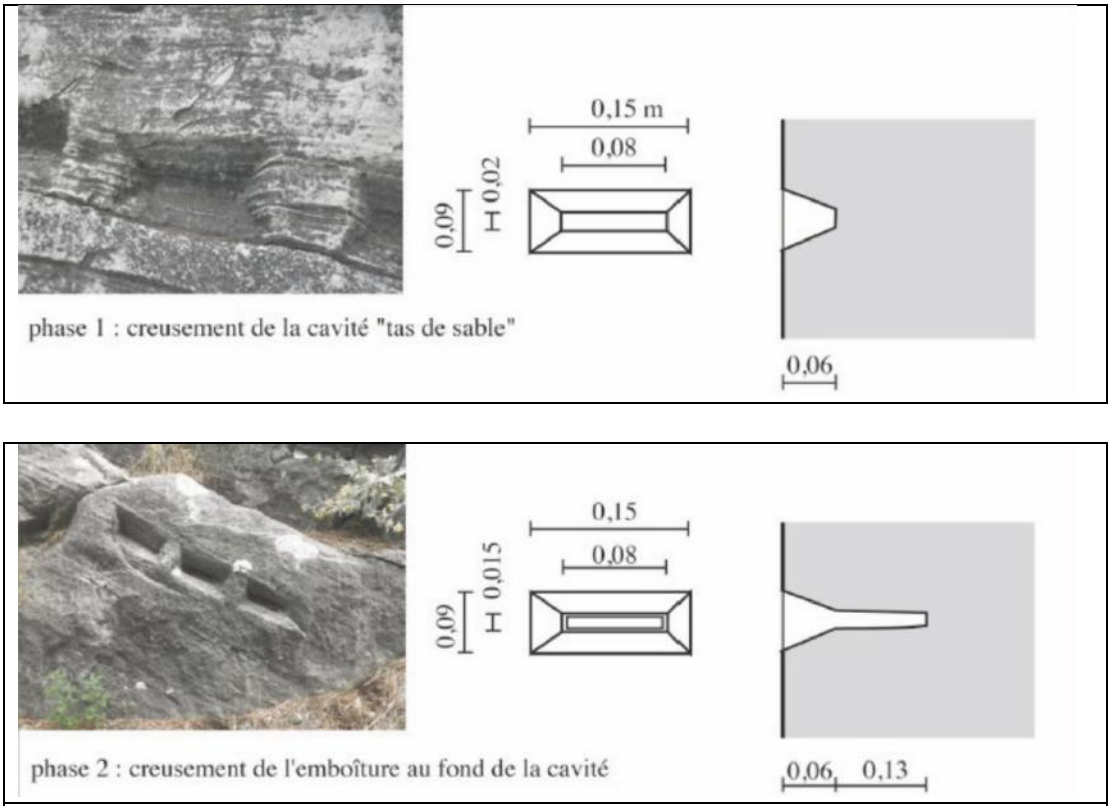

Fig. 10. Stages in the digging of an «encoignure» (photos, drawings: M.W-K.).

2.5.2. The « encoignures A »

We observe a somewhat different model of *encoignure*, with a very reduced sand heap volume and a wider socket shape (close to a trapezoid with rounded corners). Perhaps it was an atypical encoignure, therefore another type, an A one; or maybe a wide socket, a transitional model, or even a trial of a new technique.

Traces of this kind can be seen, in the quarry nearby the Lighthouse-tomb of *Akeratos* [19] at Cape Pyrgos, in the form of two alignments of respectively 6 and 7 encoignures on a working

[19] Akeratos lived around the middle of the 6th c. BC. Whether he was archon in Paros, and subsequently in Thasos or whether he was in charge of the same office for both cities, has no bearing on the dating of his lighthouse-tomb. In his memory, it was not built until the end of the

face, and another of 4 ½ corners on an abandoned block. Isolated A encoignures can be recognized in sections 10, 11 and 14 of the Ancient road from the Artemision to the acropolis. Other alignments, which were used for extraction, are also found on blocks of the foundations of the "*Machmout*" Tower.

In conclusion, this technique using A encoignure was used in the Archaic period (second half of the 6th c. BC). It seems that the technique had to respond to an urgent need.

2.5.3. The « encoignures T »

Another type of encoignure, with a more flattened sand heap volume and a narrower socket shape, hence the name "T encoignure", seems to have been used only for gneiss (fig. 11a). Traces are found on a working face of a gneiss quarry at Thasos-*Kokkinia* and on a block used in the citywall of Thasos, below Tower VII (fig. 11bc).

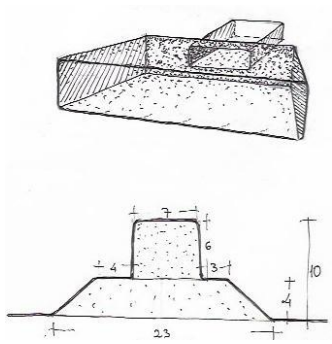

Fig. 11a. Gneiss Quarry *Kokkinia*. Drawing of the T encoignure (T.K.).

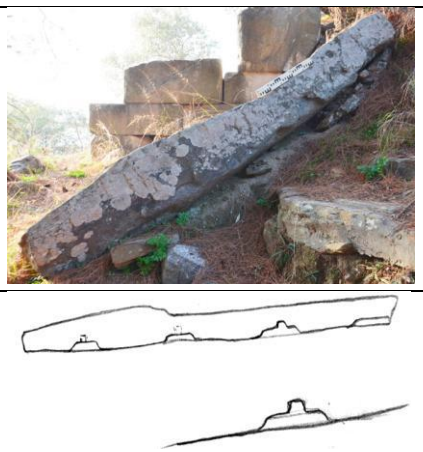

Fig. 11b. Block of Tower VII. Encoignures T and Drawing of it (M.W-K.)

Fig. 11c. Detail of the half-T encoignure (photo: M.W-K.).

Whether the T encoignure is a suitable variant for gneiss is only a suggestion, perhaps a hazardous one, for lack of other examples. The same applies to the two T-shaped tools discovered at *Kition* [20] (fig. 12), which could be compared to the prototype or considered as the template of the particular wedge essential to implement this technique.

Fig. 12. Metallic tools at *Kition* (Karageorghis, fig. XV).

6th c. BC. The presence of dovetail mortises only in the upper course of the building is also a chronological clue. (Hellmann, 2002, 93-95 et 89 fig. 97).

[20] (Karageorghis, 1976, 79).

2.6. The technique using rectangular wedge-sockets

Numerous alignments of rectangular wedge sockets, more or less spaced apart, bear witness to this extraction technique, where the wedges are struck and the block comes loose according to the splitting plane.
It is the volumes of the sockets deployed behind the rectangular orifices (of the quarrying-face) which will determine the typology, and consequently the chronology of the use of these techniques. To each standard volume will correspond its own rectangular-headed wedge template.
We offer here a state of our work, where the typology of the sockets made it possible to correlate them with three periods: Archaic, Classical and Hellenistic, Roman and Imperial. But as much as the reference points are clear for the Archaic period and well established for the Imperial period, the data are still insufficient to distinguish with certainty the wedge-sockets of the Classical period from those of the Hellenistic period.

2.6.1. The archaic wedge-sockets

The alignments from the Archaic period are composed of wedge-sockets whose volume is almost parallelepiped (rectangle, fig. 13a). The technique was used indifferently on vertical or horizontal working faces.
Sockets of this type are visible on a working face at *Folia*, where the blocks are delimited by a crack and the split-plane: they are already detached but abandoned on site. Other alignments are also recognizable delimiting non-detached blocks at *Fanari* 2 (fig. 13b).

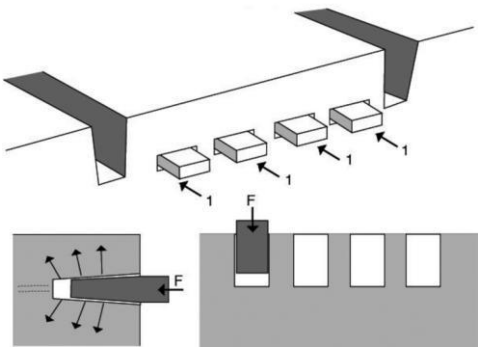

Fig. 13a. Extraction technique in the Archaic period (M.W-K.).

Fig. 13b. *Fanari* 2. Archaic wedge-sockets (photo: T.K.).

Considering the archaic terrace wall and the building upstream, it is very likely that it was this sector which provided the blocks for their construction. An isolated alignment below the lighthouse (*Fanari* 4) is a vestige of one of the quarrying exploitations. In *Aliki*, at the end of the peninsula, Jean-Pierre Sodini had identified them, and we suggest a reconstruction of the progress of this work (fig. 13c).

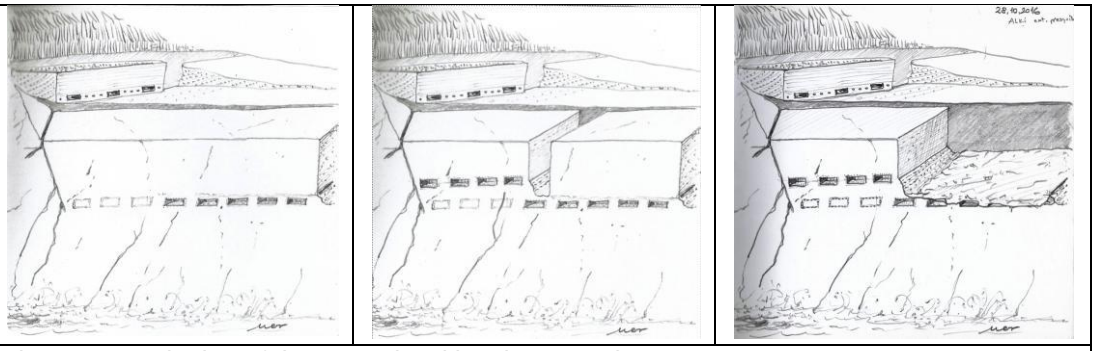

Fig. 13c. Restitution of the quarrying (drawings: T.K.).

2.6.2. The Classical and Hellenistic wedge-sockets

These sockets also have a rectangular opening, but it is the shape of the section that differs: the ends are more or less rounded (like a U) or bevelled. It seems that the wedge used has a slightly more “packed” shape to better penetrate the socket (fig. 14a). Rare alignments of this type of sockets have been identified in the quarry, some ones at *Mourgena* and others at *Saliara* 3 (fig. 14b). In the absence of traces in the quarries to differentiate the sockets, we used the traces of sockets identified on the blocks used in the constructions. Rare alignments of this type of sockets have been identified in the quarry, some ones at *Mourgena* and others at *Saliara* 3 (fig. 14b).

In the absence of traces in the quarries to differentiate the sockets, we used the traces of sockets identified on the blocks used in the constructions.

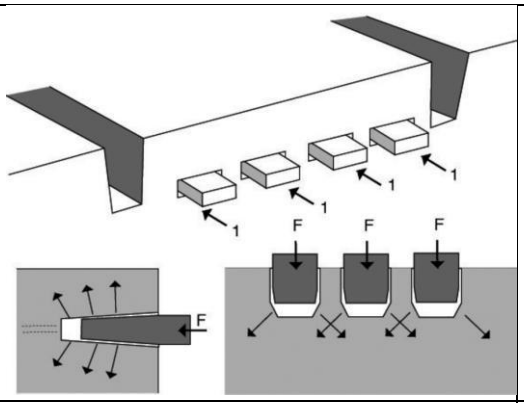

Fig. 14a. Extraction technique during the Classical and Hellenistic periods (M.W-K.).

Fig. 14b. *Saliara* 3. Alignemnt of wedge-sockets (photo: T.K.).

Although the work of cutting and adjusting the blocks on construction sites has removed most traces of the quarry work, there are sometimes some remaining on unseen faces.

These alignments of half-sockets, one on a step of stairs at the *Maritime Gate* and four on building blocks at the *North-West Stoa* at Thasos [21], can be considered as evidence of Classical era extraction. The dimensions of these sockets vary from 0.11 to 0.13m x ± 0.05m (width restored from the measurements of the ½ sockets) x 0.08 to 0.11m (depth), and are spaced 0.1 to 0.14m. Several blocks of the citywall section (Street Pavlou Mela in Thasos)

[21] (Kozelj, 1999, unpublished PhD). (Kozelj, Wurch-Koželj, AIA forthcoming). (Kozelj, Wurch-Koželj, Et.Thas. to be published). The construction of the *North-West Stoa* is to date from circa 390 BC.

have slightly different sockets: 0.175/0.11 x 0.11/0.85 x 0.10m (depth), spaced from 0.10 to 0.15m, which indicate partial re-constructions of the citywall, probably at hellenistic period.

2.6.3. The roman wedge-sockets

The sockets from the Roman period are recognized by their rectangular opening, their trapezoidal section, their regular dimensions, they are aligned, and arranged at constant intervals (fig. 15a). They reflect standardized work. Numerous alignments are identifiable on the working faces.

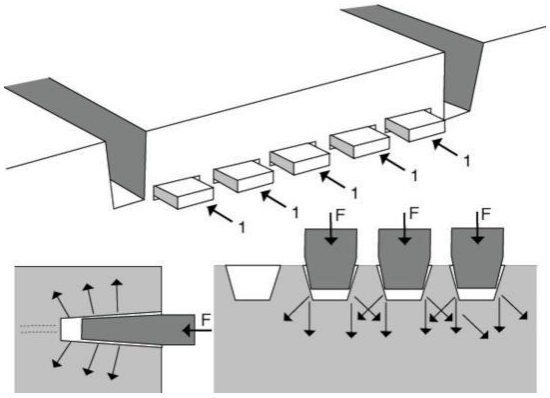

Fig. 15a. Extraction technique from Impérial period. Trapézoïdal section of the wedge-socket (T.K.).

Fig. 15b. *Agia Eirini* (photo: M.W-K.).

These alignments stand out on the working-faces of the quarries at Cap *Phanari, Fanari* 3, *Fanari* 4 at the seaside, and *Fanari* 5; so as those at *Vathy* and at *Agia Eirini* (fig. 15b).
No rectangular wedge has been identified among the metal objects from the excavations at Thasos.

2.7. The extraction technique using « mega-wedge-sockets »

The “mega-socket” is a very wide and long socket, approaching half a meter, whose profile flares out into a “corbelling”. Untill today, no large wedge has been identified to take place in such cavities. However, to fit into this “mega-socket“, a special wedge must have been designed, unless several wedges were put in place.
Traces are found on several quarry working-faces, at *Vathy* I, *Vathy* II (fig. 16ab), and *Saliara* 3.

Fig. 16a. *Vathy* II. « Mega-wedge-sockets » unused for extraction (photo: T.K.).

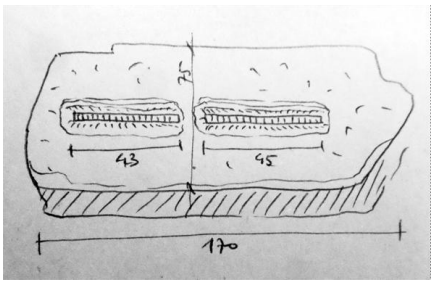

Fig. 16b.*Vathy* II. Drawing of the mega-wedge-sockets (T.K.).

In conclusion, interpreting this trace is somewhat problematic, because the isolated places where they were identified can belong to any era: is this a forgotten front from the archaic period ? Classic, Hellenistic period ? Or is it an attempt abandonned without follow-up in Roman times? Nothing really allows us to decide.

A single element that would perhaps suggest an “archaic” trace is that there is no channel dug to delimit the dimensions of the block to be extracted. Is it appropriate to see a sort of innovative technique or transition technique… in any case, it is found outside Thasos too, as at the southern quarry on *Mont Mopsion* in Thessaly [22].

2.8. The « enjarrot » technique

An “enjarrot“ is a long horizontal channel dug following the quarry-benches, at the bottom of which regular sockets are cut at constant intervals, hence the Italian expression: « *tracce di una “tagliata*” » [23].

The extraction technique using enjarrot or “tagliata“ is only identified on working faces of imposing length and depth, where the high quality of the marble means that very large blocks can be quarried. The traces left are remarkably regular, implyong the work was “standardised” and therefore indicating a rational organization of the quarry-site. This technique seems to have only been used during the imperial period.

In the absence of clear clues, the steps for extracting a very large format block can only be suggested:

1. Choice of the working face according to the dimensions of the block ordered;
2. Clearance of at least two faces, at the pick;
3. Digging of the enjarrot, this long canal (with a trapezoidal profile), with the chisel-point;
4. At the bottom of the canal are dug at regular intervals, the sockets, also trapezoidal, (chisel-point work);

But the state, witness of interrupted and unfinished work, did not allow us to observe any signs of work in the bedrock, which would have been expected to determine the width and/or depth of the block to be extracted, such as a lateral or rear channel.

The following steps are induced:

a. wedges are placed in the sockets at the bottom of the enjarrot,

b. the split-plane in the bedrock is determined by the effects of repeated hits on the wedges.

Traces of enjarrot are found mainly on very large masses of rock, from which it is possible to extract large volumes that can be to cut into labra for example (fig. 18). Remains are at the *Fanari* 4 quarry (fig. 17abc), *Fanari* 5, *Saliara* 6, *Magganiou, Marmaromandra, Vathi* III.

Fig. 17a. *Fanari* 4 Quarry (photo : M.W-K.).

[22] (Lazzarini, 2007, 223-244 ; 242 fig. 34 (photography).

[23] (De Nuccio, Ungaro, 2003, for ex. 532 n. 292).

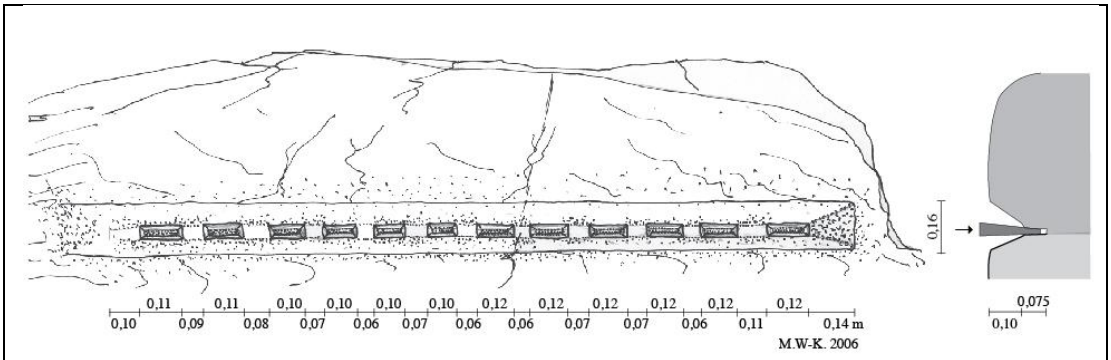

Fig. 17b. *Fanari* 4 Quarry. Drawing of the enjarrot and the wedge-sockets (M.W-K.).

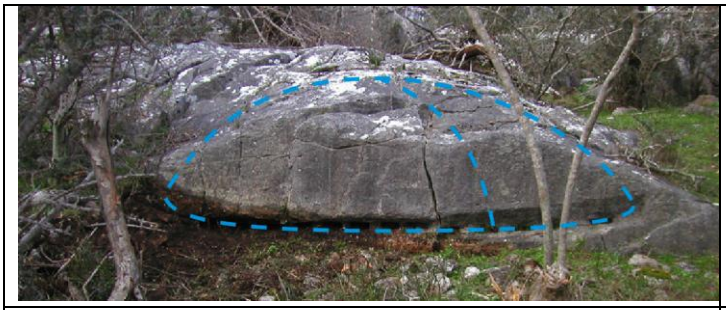

Fig. 17c. Indication of the volume that could have been extracted (photo: M.W-K.).

Fig. 18. *Labrum*. Courtyard of the Rotonda at Thessaloniki.

Wedges, at least 0.20m long, and trapezoidal in shape 0.10/0.05m wide, and approximately 0.02m thick at the tip [24], specially manufactured for this extraction technique shoud be restored.

2.9. The technique using the «composite enjarrot »

This is a variation of the enjarrot technique, where near each other, very wide notches [25] are dug out, at the bottom of the horizontal channel with a V-shaped profile.
Several examples of this “composite enjarrot” can be found in the quarries of *Saliara* 3 (fig. 19ab), and *Vathy* II.

Fig. 19a. *Saliara* 3. Composite enjarrot (photo : T.K.).

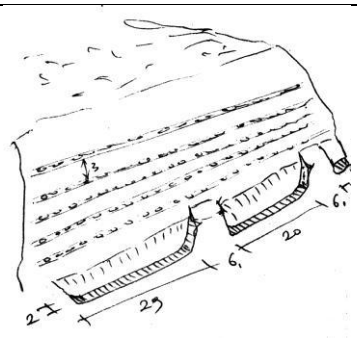

Fig. 19b. *Saliara* 3. Composite enjarrot (T.K.).

[24] The thickness of the rectangular head of this wedge stays unknown.

[25] For the composite enjarrot technique, we use the term of notch for this cut in the rock, to avoid any consusion with the mega-sockets.

2.10. The groove technique of extraction

The remains of this technique left behind are narrow and long cavities, that look like grooves ; sometimes cut into the bottom of the enjarrot.
Traces can be seen on quarry-fronts, at *Vathy* II (fig. 20a), *Saliara* 3, *Skydia*, in sector [11] of the ancient road (from Artemision to the acropolis); and also on blocks extracted (and abandoned) at *Vathy* II (fig. 20b).

Fig. 20a. *Vathy* II, Downhill quarry. Groove.

Fig. 20b. Photo L 6291, 31 (T. Koželj) shows the splitting-plane of a block, the result of extraction using the groove technique.

Special wedges had been designed to fit into these grooves.

Similar wedges were used outside Thasos. At the Chassambali quarry, where Anna Lambraki [26] identified metal wedge fragments (fig. 21a), which would be suitable for this type of narrow sockets (composite socket or groove); but also at the Eifelmuseum in Mayern [27], where two iron corners, 760 and 770 gr (fig. 21b), are dated from the 1st - 4th c. AD. They might be suitable for the groove technique. The same applies to the two "*placche per cuneo*" (fig. 21c), 0.60 m long, dated from the 2nd - 4th century, presented at the Felsberg Museum [28].

Fig. 21b. Flat-wedge (photo: De Nuccio, Ungaro, 2006, 508 n. 242-243).

[26] Thanks to Anna Lambraki, who shared with us her discovery of these flat wedge fragments, and allows us to publish her drawing (187 fig. 19).

[27] (De Nuccio, Ungaro, 2006, 508 n. 242-243). Flat-wedge from *Cava della vedova Keuser.*

[28] (De Nuccio, Ungaro, 2006, 508 n. 244-245). From the granit quarry at Felsberg.

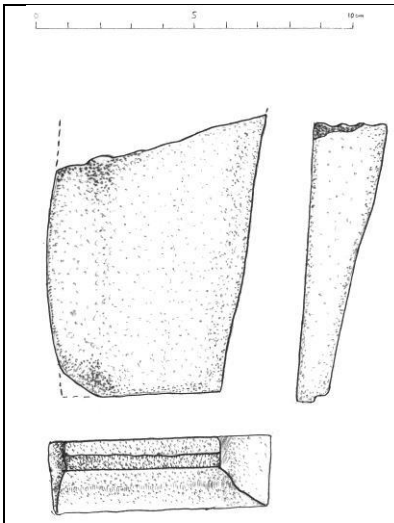

Fig. 21a. *Chassambali*. Flat-wedge fragment (A. Lambraki, 187 fig. 19).

Fig. 21c. Flat-wedge (photo: De Nuccio, Ungaro, 2006, 508 n. 244--245).

2.11. The « enfonçures » technique of extraction [29]

The technique no longer employs wedges, and only uses the chisel-point, of which the alignments of small holes are specific witnesses: repeated strikes create the split-plane, which detaches the block from the bedrock, leaving a negative (fig. 22).

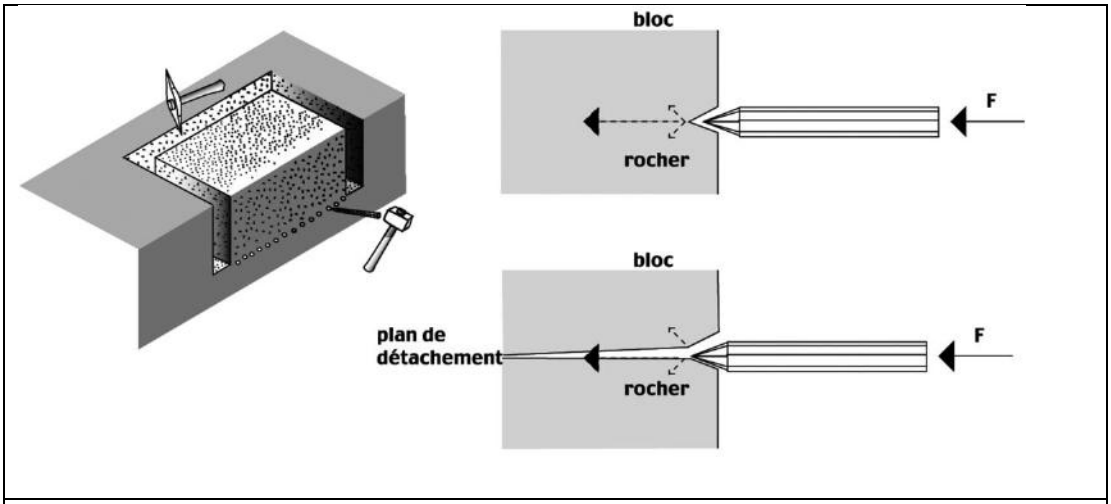

Fig. 22. The extraction technique of « enfonçures ».

Depending on the number of blows given to the point, the impact of the hole has a diameter varying from 0.02 to 0.03m and a depth of 0.02 to 0.08m (fig. 23ab).

[29] (Koželj, Wurch-Koželj, 2005, 465-486).

Fig. 23a. *Aliki*. « Enfonçures » (photo : M.W-K.).

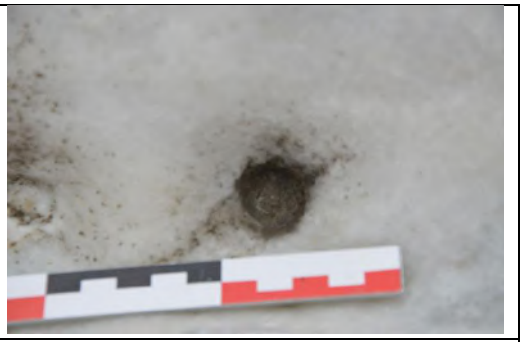

Fig. 23b. *Aliki*. Detail of an enfonçure.

This extraction technique has left countless traces (all the extraction phases are represented) on the working faces of the quarries in the South of the island, in *Aliki* [30], quarry C (fig. 24ab); in *Agios Ioannis Loukas*, in *Demir Chalkas* [31], *Archangelou* (fig. 24b), quarry *K*, which bear witness to intensive quarrying over an area around 7km^2. Marks are also in quarries near the town of Thasos, such as in *Agia Barbara*, where once again, the methodical extraction is evident. At the *Fanari* 4 quarry, there is an extraction attempt but it was surely not conclusive, hence the quarry was abandoned in the Paleochristian time.

Fig. 24a. *Aliki* C. Block with channel and « enfonçures ».

Fig. 24b. *Archangelou*. Alignemnt of « enfonçures » and showing the splitting.

This technique is also used to transform, cut up the recovered blocks from the dismantling of oldest buildings (e.g. pagan ones) into blocks more suited to the needs of new constructions (as basilicas). These traces can be seen on numerous reused blocks (building blocks, paving, and s.o., fig. 25).

[30] (Sodini, 1980, 81-137).

[31] (Kozelj, Wurch-Koželj, 2005, 465-486).

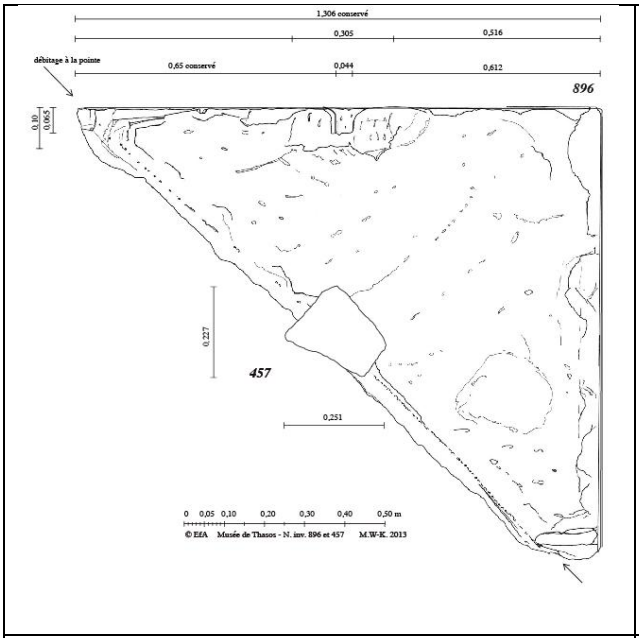

Fig. 25a. Block N. inv. 896+457, slant cut. Rear face with a string of small holes (enfonçures).

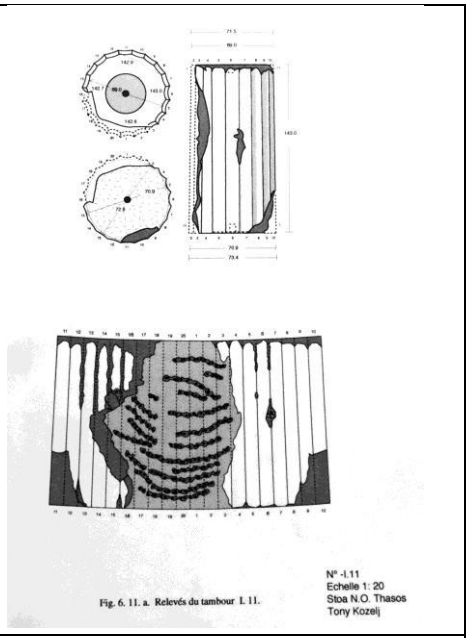

Fig. 25b. North-west *Stoa*. Drum I.11, cut in progress. (T. Koželj,1999).

In conclusion, the use of this new technique which only uses the chisel points, marks a clear break with the practices of previous techniques, since the use of the wedges is completely abandoned. This technique was established everywhere in the Paleochristian time, but it is nevertheless difficult to know the origins of its first application.

Three techniques are more complex, because they were used during Antiquity, and there are few traces of tools that allow us to date the extraction of the artifacts.

2.12. The extraction technique of monolithe shafts

This technique can be used for any elongated cylindrical element, column shaft or columnette, or ornamental base of a basin or table, for example. In general, very few abandoned remains of these small elements are left in the quarries, as extracting and transporting them posed fewer problems than those of larger volumes.

Several monolithic column shafts have been seen in the quarries, in the form of half-finished products with their protective rings at their extremities, ready to leave the quarry.

The extraction phases of a shaft can be reconstructed from the remains seen in different quarries.

- Stage 1. The dimensions of the column are materialized by the beginning of the convex size of the rock surface, and the beginning of the lateral digging [32]. Then the curved shape of the released face allows us to recognize a slightly more advanced stage of the extraction of a column shaft [33].

- Stage 2. The curved shape takes more and more the convex shape, but with the edge protection rings at their extrimities [34] (fig. 26a).

[32] *Byllis (Albania)*, Quarry I (calcaire), at paleochristian period. (BCH). (Koželj, Wurch-Koželj, 2018, 467-479).

[33] In Thasos, Quarry at *Demir Chalkas*, à *Fkiaria*, à *Aliki*.

[34] Remarkable shafts visibles at *Kylindri* and Myloi (Euboea), quarry of *cippolino*, exploited at roman period.

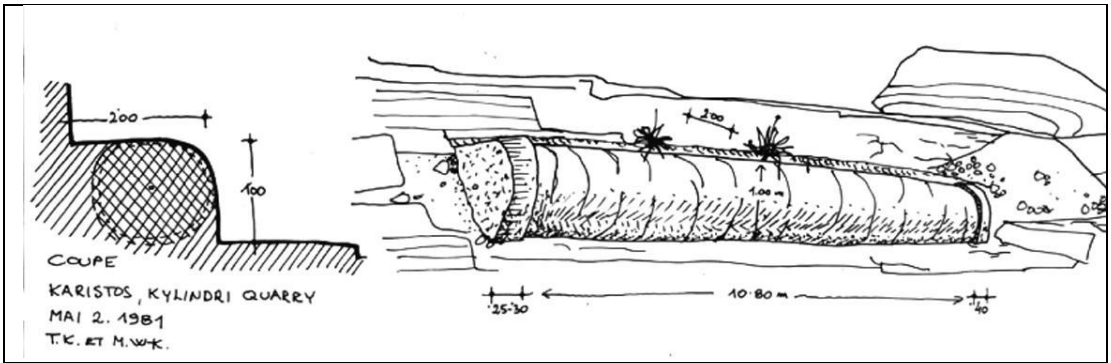

Fig. 26a. Schema of the extraction of a shaft, stage 2 (T.K. & M.W-K. 1981).

- Stage 3. The convex shape takes rough form of a column shaft (fig. 26b), but it is still attached to the bedrock by a band.

- Stage 4. After extraction from the shaft, the negative appears as a more or less concave surface; and the traces of the detachment rim (ridge) are barely visible.

Sometimes, the tools which were used for the detachment by attacking and destroying the rock strip (by which the shaft was still attached to the bedrock), left traces making it possible to recognize the method used and to propose a date of exploitation [35] (fig. 26c).

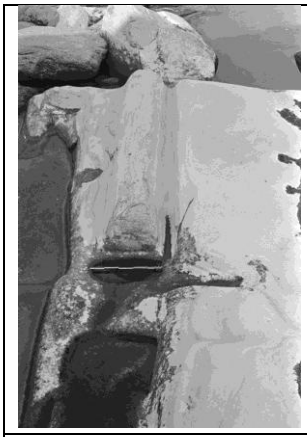

Fig. 26b. *Aliki* B8. Extraction of a small columnette, stage 2 / 3 (Paleochristian time). Cl. J.-P. Sodini.

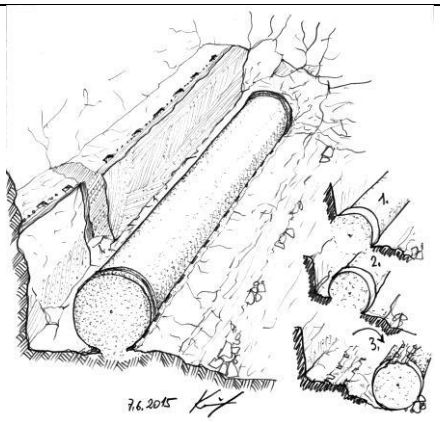

Fig. 26c. Restitution of a shaft-column extraction. Drawing: T. Koželj, schemas of the extraction stages with Naxos model, parian technique.

Although the extraction of a shaft is often isolated, it happens that a working face has made it possible, by its marble quality, to extract several shafts successively, as evidenced by the remains of at least four shafts excavated at *Demir Chalkas* (Thasos).

The shaft, detached from the bedrock, appears as a cylinder with a residue of ridge which extends over its entire length, and two rings at its ends (see fig. 28).

- Stage 5. The shafts detached and abandoned in the quarry all have their protective rings, but their surfaces have different aspects. Some are “rough” in appearance, while others are already trimmed.

- Stage 6. The residue of the detachment-bead is removed, the gangue surface of thhe shaft has a uniform appearance. This work is essential to lighten the shaft as much as possible for transport. For example, the Aliki shaft-column currently weighs around 16 tonnes. A quick

[35] Traces of Parian extraction were recognized in a concave negative, in *Naxos*.

calculation of the residual volume of the bead allows us to estimate its weight of approximately 240kg. Removing this residue would further reduce the weight of the barrel to be transported.

- Stage 7. The shafts were moved many times, from the extraction-place, the cutting workshop and were stored on storage platforms, ready to be loaded.

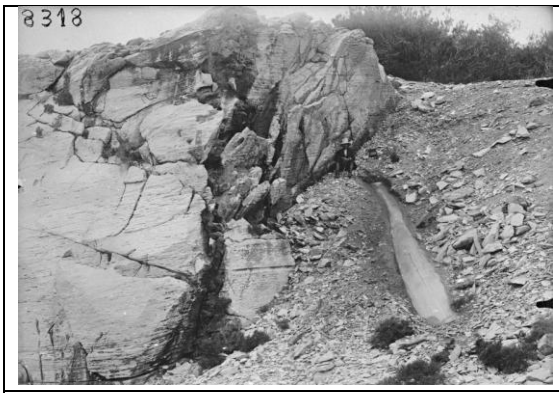

Fig. 27a. Column-shaft in *Aliki*, cl. EFA 8318.

Fig. 27b. Stage 2003.

In the lower part of the *Aliki* B10 and nearby the location of a lifting machine, two shafts (currently fragmentary) must have been ready for transport. In the cuttings-debris from *Aliki* B10, a single complete shaft with its protective rings at its extremities was found (fig. 27ab, 28a) [36].

It was abandoned during work in progress. Two letters AK are engraved [37] on the upper ring (fig. 28b). This is a monogram [38]. The stage of abandon of the shaft (still the residue of the detachment-bead is not removed) excludes the mmongram of the controller, who would attest the conformity of the ordered artifact and authorizing its departure from the quarry.

Fig. 28a. *Aliki* B10. Shaft Column. Detail of the protective ring and the residue of the detachment-bead.

Fig. 28b. On the upper ring detail of the monogram AK.

[36] Thanks to the French School of Athens, to have authhirize me to publish the photo EFA 8318, our fig. 27a.

[37] The caracteritics of the letters don't allow to date the shaft.

Marks have been found in the quarry *Krio Nero* (Euboea), which had belong to the emperor ; also in *Mons Claudianus* quarries (Peacock, Maxfield, 1997, 216-231) and in *Saraylar* and *Ilik* (Marmara / Proconnesos (Asgari, Drew-Bear, 2002, 1-19). Minium paint-marks are still visible on blocks in *Ilik* and *Aksoy* / Proconnèse (Asgari, Drew-Bear, 2002, 10-16).

[38] Monogram may perhaps be the one from the quarry-stone cutter, or that of the name of the owner, the concessionaire or even could be that of the tenant of the quarry. But it could be also a monogram in relation with the artefact order.

More generally, it is the letter Π, isolated, engraved on the column shaft gangue [39], which is to be considered as an abbreviation of παραλαβή [40] (at the classical and Hellenistic periods) or probavit (during imperial period), indicating that the artefact was controlled and ready to leave the quarry

In conclusion, we emphasize that the shafts are extracted in the knowledge that they will be placed in a wrong way. This is understandable from the point of view of the quarrying and the possibilities (natural constraints) of extracting, but it still has a major disadvantage from the "technical – resistance of materials" point of view: resistance to compression, and endurance, are not required. Vertical micro-crackings are inevitable under excessive loads (from the upper layers), and vertical deterioration is a witness to their poor aging, if only due to bad weather (as the shaft of the South-East portico of the Agora in Thasos). This is also one of the reasons why column drums were used, from a static point of view (especially beyond a certain diameter).

2.13. The extraction technique of cylindres

The major element of this extraction technique is to obtain products, able of supporting significant loads and resisting significant pressures, they are taken according to the to the quarry bed (veins) and implemented in this way in the work. In Thasos, we have not identified any trace of the extraction of "mega-cylinders" transformed into immense column drums, specimens of which are found in the quarries of *Cava di Cusa,* in Selinunte, Sicily.

2.13.1. The extraction of medium and small format cylinders (grinding wheel // millstone type)

The extraction technique used to extract medium and small format cylinders, or approximate shapes, slightly conical, is almost the same, only the scale and proportions change. A peripheral channel is dug from the surface, its depth corresponds to the height of the desired product, and its narrow width further diminishes towards the bottom of it (reduced to the thickness of the chisel-point). The profile of the canal sometimes forms a V, in which the hand can barely hold the chisel-point properly.

Several channel profiles present "stenosis", these rings due to successive narrowing of the channel width as a function of depth fig. 29a). These are witnesses to the essential work (no useless or superfluous work), necessary to reach the desired height, clear and erect the cylinder surface. In *Agios Ioannis Loukas*, the circular negative shows three stenosis of the channel, which make it possible to restore the successive widths of the canal, from top to bottom: the greater one 0.40m, a narrowing from 0.40 to 0.25m, then another shrinkage from 0.25 to 0.05/0.04m, as shown in the diagram (fig. 29b).

[39] The letter Π was seen on a shaft at *Krio Nero* quarry (Euboea).

[40] Παραλαβή, Παράλαβε, Παραλαβών have been found on buidings of classic and hellenistic period; as inside the tomb of *Kasta* at Amphipolis. (Peristeri, Lefantis, Unpublished).

Fig. 29a. *Agios Ioannis Loukas*. Circular negative and « sténosis » (photo: M.W-K.)

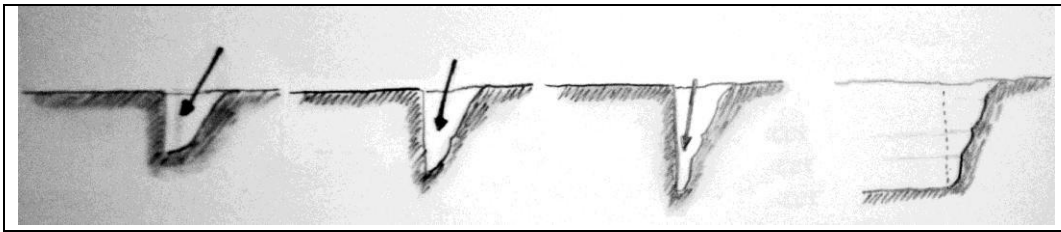

Fig. 29b. Stenosis. Schema: progression of the channel dinging with largness shrinkages in relation of the depth (M.W-K.).

In Thasos, many circular negatives can be seen in several working-faces of the quarries C at *Aliki*, also at *Agios Ioannis Loukas, Skydia, Fanari* 4, *Glykadi* 3, *Skydia*; as well as cylinders still attached to the bedrock, at *Fanari* 3, *Saliara* 3, *Glykadi* 3.

Given the depth and sometimes narrowness of the V-shaped channel, a special chisel-point must have been made. At Thasos, no kind of this chisel-point was recognized. In contrast, at *Rizoklimata* in Cyprus [41], a long chisel-point was identified (fig. 30) and is similar to the tool necessary for digging peripheral channels.

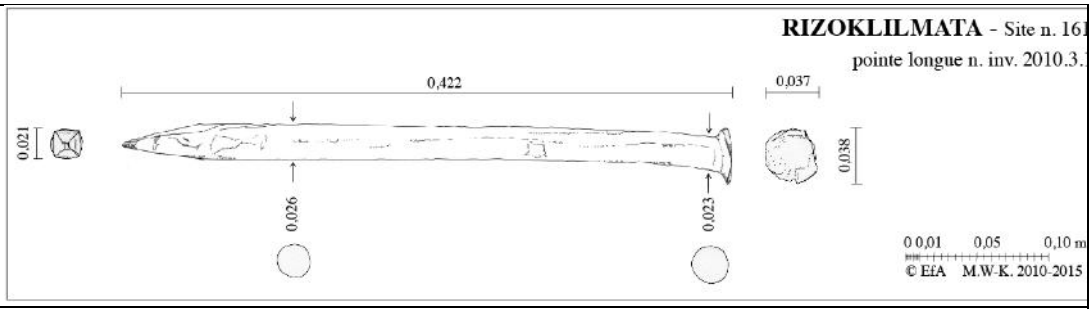

Fig. 30. *Rizoklimata* Long chisel-point n. 161 (M.W-K.).

2.13.2. The extraction of large format cylinders (drums)

Several methods of extracting drums have been recognized, having left certain traces.

Method 1 is explained by Manolis Korrès [42]. He implicitly lets us understand that in the Pentelic quarries, the column drums of the Parthenon are extracted in the same way as the capitals; that is to say a rock mass is extracted, from which the shape of the drum with protuberances is roughed out (to attach the ropes necessary for its movements)

[41] (Petit-Aupert, to be published).

[42] (Korrès, 1992, 8-17, and 1995, 1-5).

Some traces in the *Xenochorafi* marble quarry (near Drama), as negatives of rectangular blocks, so as an unused extraction preparation for another rectangular block, or circular cavities for feet (restitution of a tripod), — a circular negative on middle of these remains, or even a free space (intra-site road, in green on the photo montage), etc., are the “palimpsests” which allow us to support method 2 (fig. 31).

Fig. 31a. Drama. Quarry *Xenochorafi*. Negative of a cylinder extraction (2002).

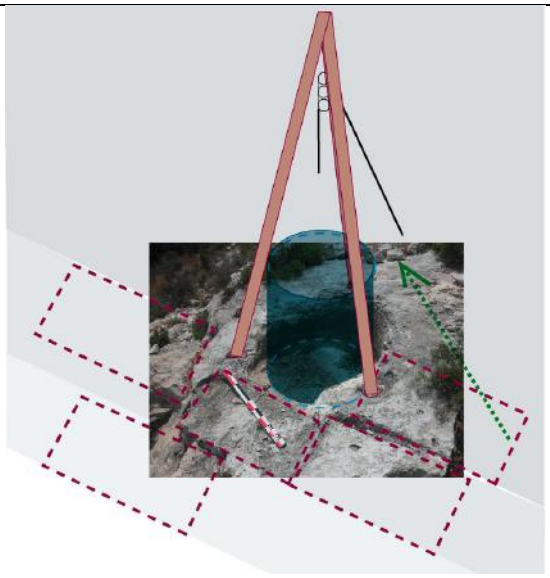

Fig. 31b. Interpretation of the remains.

In Thasos, no large format cylinder extraction negatives have been observed so far. However, a large cylinder (ø 1.94m, 1.30m thick) with a remnant of a protuberance (a cladding tenon), can be found in the *Aliki* C quarry (fig. 32). Due to its location near traces of the location of a powerful lifting machine, it was considered as a counterweight, according to its weight, approximately 11 tons. But it could just as easily be a column drum waiting to be transshipped. Its lapidary mark K, 0.26m high, gives us no clue.

Fig. 32. *Aliki* C. Cylinder (photo: T.K.).

2.14. The technique used to extract sculptures [43]

Could a sculpture be carved out from a parallelepiped block which previously was extracted ? Taking into account the carving out techniques, the unusable mass of marble turned into debris, the process is strange to conceive, but exceptions might exist. The shape of sculpture was, -as the coulumn-shaft-, carved out directly from the bed-rock. Its overall shape was given as its extraction progresses. Two methods have been noticed: the extraction-carving of the back lying rough-shape (face to sky), and the second one where the rough-shape is lying on the side (face looking in front, to the sculptor) [44].

2.14.1. The extraction technique of sculpture back-lying

At Thasos, even fragmentary of products of « gigantism », have not been identified yet the marble allows it.

But from references outside Thasos, taking into account the negatives in the quarry and the remains of sculpture [45], it is possible to extrapolate and restore the stages of the extraction technique.

The choice of the quarry-front is very delicate and must be judicious to extract large or hudge sculptures. The option of finger quarry is restrictive and constraining in volume, but not in work: remove the excess material to accurate its volume closer to its ordered shape. We suggest the succession of stages:

1. Choosing the finger-quarry in which the ordered volume fits ;
2. The volume is rough-cut down from the top to the sides, according with the thickness needed for the sculpture, the Stone-cutter carved the wedges holes with a long chisel-point at the bottom, which will be the back-side of the sculpture.
3. Special long wedges, put in the holes, hidden together, created the split-plane to detach the volume from the bed-rock.
4. Stays the bed-rock with the negative of the extracted volume and the remains of the half wedges-holes.
5. The following step is probably done by more qualifited Stone-workers, maybe by Stone-masters or Sculptors, and consisted to rough-hew the volume for approaching (the more possible) the ordered shape, but in keeping the protection enveloppe needed for transport. At this state, the quality of the marble piece without default was confirmed. This work was also done to lighten it to be transported from the quarry to its purpose place.

At Thasos, among all the rock-masses at *Treis Gremmous*, one is to be assimilated to a finger-quarry, which presents a « rough-volume » and a flatted platform on a side. This « rough-volume » as a first draft of sculpture [46], may to be related to a *kouros* (or a *kore*) and has been abandonned during its extraction, probably due to the crack on its right side. On the boundary between the rough-volume and the platform, cavities, one next to the other, have

[43] (Koželj, Wurch-Koželj, *ASMOSIA* XIII. Forthcoming).

[44] (Wurch-Koželj, 2018, 54).

[45] At Apollonia at Naxos, the colossal sculpture. An other abandonned colossal sculpture has been identified at Mont Pentelique. The upper part of a sculpture is unfinished, rough-hewed. (Kozelj, Wurch-Koželj, forthcoming ASMOSIA XIII. fig. 2ab).

[46] It's during a prospecting /expertise (July 30th 2019) requested by the Ephoria of Kavala, that we have identified towards « Treis Gremmous » this rough shape of sculpture.

We thank Stavroula Dadaki, Ephorate of Kavala, and Konstantina Panousi, for allowing us to publish this find.

been deeply dug by long chisel-point. These kind of cavities are related to large wedge-holes, the « *encoignures* » [47], that were used in the extraction technique of the archaic period.

Here, the extraction process has stopped, and the alterations of the surface don't allow us to identify other-marks of tools.

A parenthesis about the colossal unfinished *kouros*, which is exhibited at the Archeological Museum of Thasos (inv. Λ1[48]). The first noticing is its trapezoidal shape (flared from bottom to top), with a narrow base-plinth and large shoulders, which indicates that it was extracted from a finger quarry [49]. We did observe others work traces done at the quarry which still were not removed.

1. The texture of the top of the right hand [50] could be the result of the erosion due to its long stay into the city walls (under the cistern), but it seems to correspond to the original epidermis of the marble vein.
2. A shallow engraved Π on its right shoulder (scapula), which implies that the *kouros* had been checked to leave the quarry area: its caracteristics were verified, according to the ordered sculptur.
3. Four types of chisel point marks have been identified (also confirmed by Danièle Braunstein [51]), and indicate the phases of work [52]. The ones of rough-hewing, visible in the lower part of the *kouros*, its feet and legs, were done with a « long chisel-point » by stone-cutters, at the preparation area of the quarry.

The *kouros* was rough-shaped, keeping a thin « enveloppe de protection » (an extra thickness of marble to protect the surface in the event of bad handling during the transport), and it was verified (Π), so that it could leave the quarry. It arrived well at its purpose place, since the work in the shape of the hair and the ram was in progress, carved and hewed with fine chisel-point by stone-masters or sculptors [53].

For lack of remains and references to unfinished *kouroi* or quarries, to say that the « finger-quarries » were exploited only from the end of the 7th c. to the beginning of the 6th c. B.C. stays a judicious hypothesis.

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[47] (Wurch-Koželj 2018, 51-52 fig. 2). (Kozelj, Wurch-Koželj, forthcoming ASMOSIA XIII).

[48] (Pottier 1920, 218-223). (Picard 1921, 86-173). (Koželj 1988, 13, pl. 1, fig. III.2 2. *Kouros* criophore de l'acropole de Thasos; and 57, pl. 57, fig. 13 transport). (*Guide de Thasos* 2000, 111 and fig. 65; 245 and fig. 171a, b, c).

[49] This shape indicates a stage, which only makes sense if it reflects a constraint linked to the initial volume of marble available.

[50] The hand must have been closest to the surface of the available marble volume.

[51] (Braunstein 2018, 711-716). We agree with the statements of Danièle Braunstein, except for the extraction of the *kouros*.

[52] Work from the rough-hewing done by stone-cutter at the quarry to the thin sculpted hair shape done by a stone-master / sculptor. The progression of the work was from the top to the bottom.

[53] The datation of this unfinished *kouros* is given by Bernard Holtzmann according to the stylistic aspects: Translation: « *the hair in large pearls is still that one of the 7th c.*», « *the headband tied around the head … as in the Attic kouroi of the beginning of the 6th c.*»; nevertheless the dating held is *« 600 B.C. »* (Guide de Thasos 2000, 246, fig. 171abc). (Holtzmann 1978, 294-295, fig. 181abc).

2.14.2. The extraction technique of sculpture side-lying.

When we identificated the « rough-volume » at the South Quarry at Byllis (Albania), we immediately thought of the rough-volume [E1] from the quarry Vathy II in Thasos [54]. Although one (Byllis) is still attached to the main-bedrock, and the other one (*Vathy* II) is detached and was abandonned in the quarry, they present a similar-shape (fig. 33).

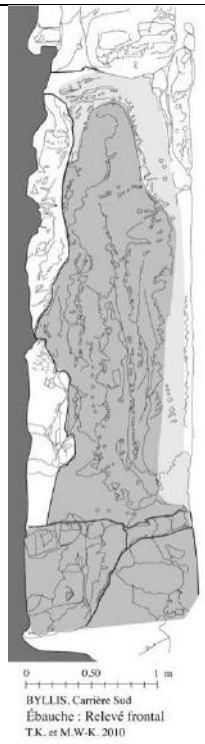


Fig. 33a. The sculpture shape attached to the bedrock of the quarry in *Byllis* (Albania). Rotation of the drawing to show the similarity of the two shapes.

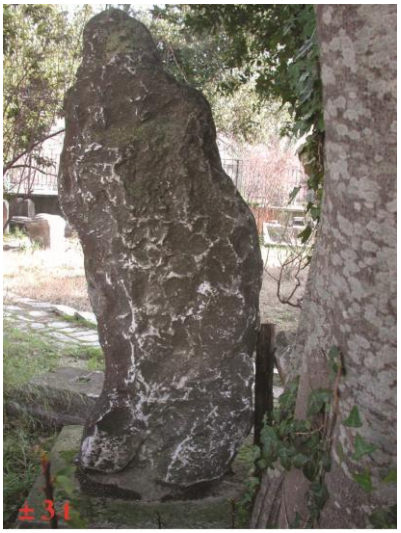


Fig. 33b. Sculpture shape of *Vathy* II in the courtyard of the Archaiological Museum,Thasos (photo: T.K.).

We proposed to see the same technique of extraction of the sculpture side-lying, the shape is given, in lenght by a channel at each extremity, and the quarrying will go on from the top, carving the ”round” rought shape of the side, carving the front part of the sculpture, and diging the rock to roughly give the shape of the back side. When the three sides are getting on for a shaped form, it will be detached by a scission plan, which will match the other side of the sculpture.

In conclusion, it seems that extraction in the finger-quarries was abandoned in favor of extraction in the working-faces, while maintaining for a certain time, the “lying on the back” process (experience acquired by the extraction of kouroi [55]), before transferring the “laterally lying” extraction method; but these are only hypotheses.

[54] Summer 1981, Tony Koželj had discovered the rough-volume at the quarry *Vathy* II. For his request and with the help of M. K. Filipidis, who provided a truck and workers to help Tony to transport it, the rough-volume entered the Archeological Museum of Thassos (Inv. Λ4068) and where it stays in the garden.

[55] The colossal sculpture at Apollonia (Naxos) bears witness to this, which may explain thhe confusion over its identification.

2.15. The saw extraction technique

In the quarry, the technique of extracting blocks using a saw is known from the restitution of the single-blade pendulum saw (fig. 34) made by Joseph Röder [56], and from several saw blades (fig. 35) discovered in quarries.

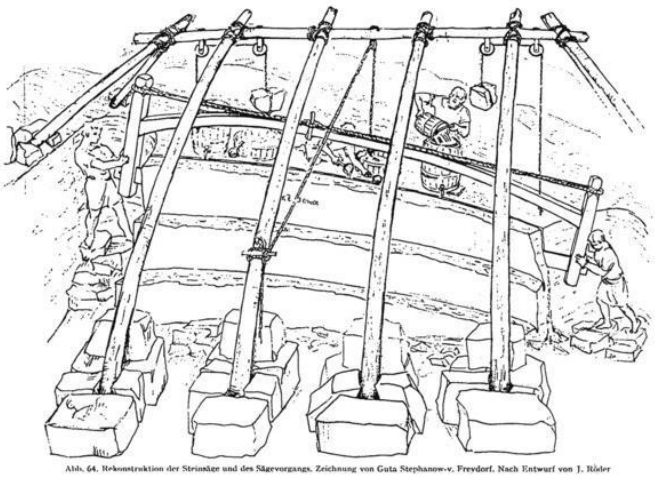
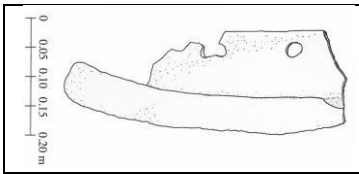


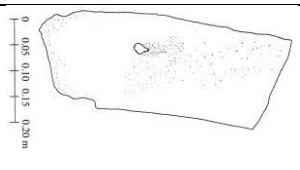
Fig. 34. Single-blade pendulum saw, restitution J. Röder.

But in Thasos, until now, no trace that could be related to the quarry saw extraction technique has been identified; but that does not mean that it was never used to extract marble from working faces. This process nevertheless seems very restrictive and, in our opinion, “ill-suited” to Thasian exploitations, and therefore “unprofitable” compared to other extraction techniques.

Among the saw baldes idendified, the most remarkable one measures 4.50m long and was identified in the Roman quarries of Felsberg by Cohausen and Werner [57]. In Euboea, in the Chassambali quarry, Anna Lambraki [58] also recognized several saw blades. Their traces of wear testify to their intensive use. These are smooth blades 3 to 5mm thick. One of them (fig. 35. Blade 3) must have measured approximately 2.50m long.



Blade 1.

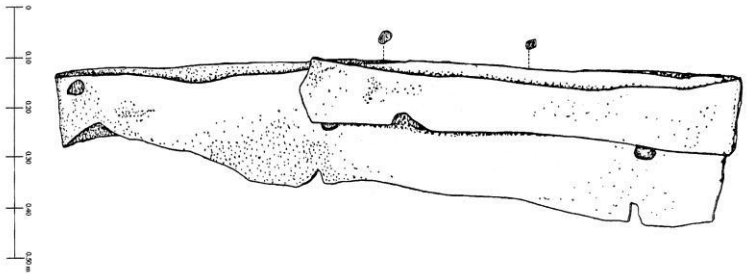


Blade 2.

[56] (Röder, 1971, 301-312).

[57] (Cohausen, Werner, , 31).

[58] (Lambraki, 1982, 81-88). (Lambraki, unpublished PhD: fig. 183, 184-186). Quarry *Chassambali.* A4: blade 1, thick. 5mm ; blade 2, thick. 3mm (érosion avancée); quarrry B2: blade 3, cons.L. 1,24m, thick. 3 to 4mm. Thanks to Anna Lambraki, who allows us to publish her unpublished drawings of the saw-blades.



Blade 3.

Fig. 35. *Chassambali* (Euboea). Quarry A4: saw-blades 1 et 2; Quarrry B2: blade 3. (drawings: A. Lambraki).

There is no doubt that the activity of sawing cippolino is attested in the quarry, but were these blades attached to a “pendulum saw structure” installed above the working face to extract cippolino from the bedrock by sawing, in the way that Joseph Röder (above) had restored it, or had these blades belonged to a “saw” installed in the cutting workshop (open space) associated with this exploitation, transforming the extracted blocks in different modules of blocks and/or slabs depending on the orders.

The current state of research does not allow us to comment.

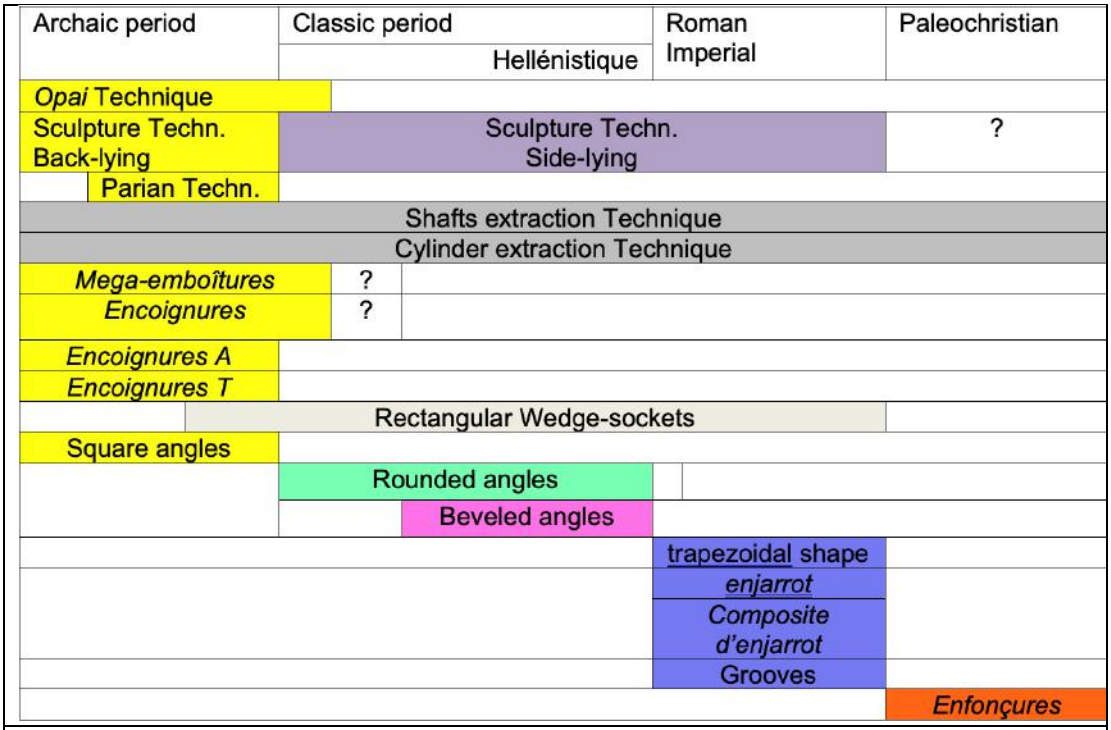


Fig. 36. Summary table of techniques in relation to the different periods of Antiquity (T.K. & M.W-K.).

3. Conclusions

Marble in Thasos has therefore been exploited since ancient times, and the traces in the quarries indicate successions of exploitation using different techniques. The absence of a trace of a technique does not necessarily mean that this tecnique was not used, because subsequent exploitation may have caused all traces of the previous exploitation to disappear.

Likewise, it should always be remembered that one technique does not drive out the other overnight and that two techniques can coexist for a more or less long period of time.

The summary table schematizes the use of the techniques respectively used during the different periods of Antiquity.

Bibliography

AJA	*American Journal of Archaology*
ASMOSIA	*Association for the Study of Marble and Other Stones in Antiquity*
BCH	*Bulletin de Correspondance Hellénique*
CRAI	*Comptes-rendus de l'Académie des Inscriptions et des Belles Lettres*
JDAI	*Jahrbuch des Deutschen Archaeoligischen Instituts*
Ét. Thas.	*Études Thasiennes*
RA	*Revue d'Archéologie*

Asgari, N., and Th., Drew-Bear. 2002. The quarry inscriptions of Proconnesos, in J.J. Herrmann, N. Herz, R. Newman (éds), *Interdisiplinary Studies on Ancient Stone*, Proccedings of the fifth International Conference, *ASMOSIA* V, Museum of Fine Arts, Boston 1998, Archetype Publications, 2002, 1-19.

Braunstein, D. 2018, The different steps of the rough-hewing on a monumental sculpture at the Greek Archaic period: the unfinished kouros of Thasos, in D. Matelic-Poljak, K. Marasovic, Proceedings of *ASMOSIA* XI (Split 2015), 2018, 711-716.

Cohausen, W. *Römischen Steinbrüche auf den Felsberg.*

Daux, G. 1962. Mytilène, *Chronique de fouille, BCH* 86, 1962, 876-879.

De Nuccio, M. and Ungaro L., 2003, *I marmi colorati della Roma imperiale,* P. Pensabene, L. Lazzarini (éds.), Rome 2003. Collaboration de M. Bruno, M. Milella, S. Pergola, S. Violante.

De Nuccio, M. and Ungaro L., 2006, Colour and marble in early imperial Rome, *The Cambridge Classical Journal* 52, 2006, 1-22.

DOI: https://doi.org/10.1017/S1750270500000440

Grandjean, Y. 1988. *Recherches sur l'habitat thasien à l'époque grecque*, *Ét. Thas.* XII, 1988.

Grandjean, Y. 2011. *Le rempart de Thasos*, *Ét. Thas.* XXII, 2011.

Grandjean, Y., and Salviat Fr., 2000, *Guide de Thasos*.

Hellmann, M.-Chr. 2002. *L'architecture grecque* I*. Les principes de la construction*, Paris 2002.

Holtzmann, B.1978, *Οδηγός της Θάσου*.

Karageorghis, V. 1976, *Kition*.

Koukouli-Chrysanthaki, H. 1987. 389-431, 1992, Πρωτοϊστορική Θάσος: Τα νεκροταφεία του οικισμού Καστρί*,* ΑΔΔημ.45, 1992, 692-697.

Korrès, M. 1992. *Vom Penteli zum Parthenon*, Glyptohek München, München 1992, 8-17.

Korrès, M. 1995, The ancient quarries on Mount Pentelikon, in Y. Maniatis, N. Herz, Y. Basiakos (éds), *ASMOSIA* III, Athens May 1993, London 1995, 1-5.

Koželj, T. 1983. Une voie d'accès à l'acropole de Thasos, *BCH* 107, 1983, 717-744.

Koželj, T. 1988. Les carrières des époques grecque, romaine et byzantine : techniques et organisation », in J.C. Fant (éd.), *Ancient Marble Quarrying and trade. Colloquim of san Antonio 1986, BAR International Series* 453, 1988, 3-79.

KOZELJ, T. 1999, unpublished PhD. La *Stoa* Nord-Ouest de Thasos, Thèse-Doctorat d'Archéologie, Université de Lyon II.

Koželj T., AND, Wurch-Koželj, M. 1992b. The Préparation of Blocks for transportation in Antiquity : "initial shape and protective envelope", in D. Decrouez, J. Chamay, F. Zezza (éds), *La Conservation des Monuments dans le Bassin Méditerranéen, Actes du 2è Symposium International,* (Genève 1991) 1992, 501-517.

Koželj T., AND, Wurch-Koželj, M. 2005. Les carrières de marbre à Thasos à l'époque proto-byzantine, extraction et production », *Mélanges Jean-Pierre Sodini,* Paris 2005, Association des Amis du centre d'Histoire et civilisation de Byzance, *travaux et Mémoires* 15, 465-486.

Koželj T., AND, Wurch-Koželj, M. 2009, Les carrières du Cap Phanari à Thasos, in Ph. Jockey (éd.) Marbres et autres roches de la Méditerranée antique : études interdisciplinaires, *ASMOSIA* VIII, Aix en Provence, Paris 2009, 49-71.

Koželj T., AND, Wurch-Koželj, M. 2012a. Limestone quarries in Byllis, Albania, in A. Gutiérrez Garcia-Moreno, P. Lapuente Mercadal, I. Rodà de Llanza (éds), *ASMOSIA* IX, Tarragona, 2012, 619-627.

2012b, Use of a Saw in Roman and Proto-Byzantine Period on the Island of Thassos, in A. Gutiérrez Koželj T., Wurch-Koželj, M. Garcia-Moreno, P. Lapuente Mercadal, I. AND, Rodà de Llanza (éds), *ASMOSIA* IX, *(*Tarragona, 2009*),* 2012, 715-722.

Koželj T., AND, Wurch-Koželj, M. 2018. Les carrières de calcaire de Byllis, in J.-L. Lamboley, L. Përshita, A. Skenderaj (éds), L'Illyrie méridionale et l'Épire dans l'Antiquité VI, VI[e] colloque international au Musée de Tirana (20-23 mai 2015), Tirana-Paris 2018, II, 467-479.

KOZELJ T., AND, WURCH-KOZELJ, M. 2023. The extraction technique with square-head wedges at Thasos (Greece), in Yavuz Ali Bahadir, Yolaçan Burak, Bruno Matthias (éds), *ASMOSIA* XII, (Izmir 8-14 October 2018), 2023, 421-428.

Koželj T., AND, Wurch-Koželj, M. A new approach to the North-West *Stoa* of Thasos. *AIA* forthcoming

Koželj T., AND, Wurch-Koželj, M. The extraction techniques of sculptures. Thassos (Greece). *ASMOSIA* XIII. Forthcoming.

Koželj T., AND, Wurch-Koželj, M. La Stoa Nord-Ouest à l'agora de Thasos, *Et. Thas.* to be published.

Lambraki, A. unpublished PhD.

LAMBRAKI, A. 1980. Le cipolin de la Karystie. Contribution à l'étude des marbres de la Grèce exploités aux époques romaine et paléochrétienne, *RA* 1, 1980, 31-62.

LAMBRAKI, A. 1982. L'emploi de la scie lisse en tant qu'outil de carrier en Grèce, à l'époque paléochrétienne, dans Troisième journée de l'industrie minérale, le marbre, (Namur 16-18 novembre 1981), Rapport d'Archéologie et d'histoire de l'art, Bulletin des musées royaux d'art et d'histoire (*BmusArt)* 53, 2, 1982, 81-88.

Lazzarini, L. 2007. *Poikiloi lithoi, versiulores maculae : i Marmi colorati della Grecia Antica*, Fabrizio Serra (éd.), *Marmora* 2, 2006, Suppl. 1, Pisa, Roma, 2007.

Peacock D.P.S., and, Maxfield V.A. 1997. *Survey and excavation Mons Claudianus*, I. Topography and quarries, 1987-1993, I, *FIFAO* 37, 1997.

Peristeri K., and, Lefantis M., The tomb of *Kasta* at Amphipolis, Conference at Thessaloniki 2015, 30th september. Unpublished.

Petit-Aupert C., *Chôra d'Amathonte*, *surveys*, to be published by EFA.

Picard Ch. 1921. Fouilles de Thasos, *BCH* 45, 1921, 86-173.

Pottier E. 1920. Un colosse "criophore" archaïque découvert à Thasos, *CRAI* 64, 1920, 218-223.

Röder J. 1971. Marmor Phrygium. Die antiken Steinbrüche von Iscehisar in Westanatolien*, JDAI* 86 1971, 301-312.

Servais. J. 1980. *Aliki I, Les deux sanctuaires, Ét. Thas*. IX, 1-78.

Sodini J.-P., Koželj T., and, Lambraki A., 1980, *Aliki I. Les carrières de marbre d'Aliki à l'époque paléochrétienne, Ét. Thas*. IX, 1980.

Wurch-Koželj M. 2017. PhD unpublished. *Les carrières de Thasos : étude technique et socio-économique.* Thèse–Doctorat d'Archéologie, Paris-Sorbonne-Panthéon 2017.

Wurch-Koželj M. 2018, Les carrières antiques de marbre à Thasos : des vestiges à la notion d'écosystème, in A. Gutierrez Garcia-M et P. Rouillard (éds), *Lapidum Natura Restat, carrières antiques de la peninsule ibérique dans leur contexte (chronologie, techniques et organisation de l'exploitation),* actes du colloque (Madrid - Casa De Velas-quez, 8 et 9 février 2016), *Documenta* 31, *Collection de La Casa De Velazquez* 170, Tarragona-Madrid 2018, 49-63. Conferencia de clausura.

Wurch-Koželj M., Koželj T., 2024, Σαλιαρα-Βαθυ. Τα αρχαια λατομμεια: απο τα ιχνη, η τεχνικη μελετη μεχρι την εννοια του οικοσυστηματος. Θασιακα, Θ' Συμποσιο Θασιακων Μελετων. Η Θασος δια έσου των αιωνων. Ιστορια - Τεχνη - Πολιτισμος, 24, 473-518.

ΑΙΓΙΔΑ

ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
Υπουργείο Πολιτισμού

ΧΟΡΗΓΟΙ

ΥΠΟΣΤΗΡΙΞΗ