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IDENTIFICATION OF STONE BLOCKS USED FOR THE BUILDING OF THE *THYSDRUS* AND *THAPSUS* AMPHITHEATRES IN TUNISIA*

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In Tunisia, the largest amphitheatre (known as the Coliseum) at Thysdrus *(El Djem), with some parts of the second amphitheatre, and the* Thapsus *amphitheatre have been built with squared stone blocks (*opus quadratum*). The petrographic and geotechnical analyses of the samples taken from the amphitheatre blocks show that these blocks belong to the Tyrrhenian and to the Mio-Pliocene age. Ancient quarries have been found on the Tyrrhenian dune line between Hiboun and Al Alya, at a distance of 30 km from* Thysdrus*, from which the Tyrrhenian blocks have been extracted. Concerning the Mio-Pliocene blocks, they have most likely been cut from just one ancient quarry found in the hill of Ksour Essaf. The height of almost all of the measured blocks from the* Thysdrus *Coliseum is equal to the Punic cubit used at Carthage (50 cm), and the height of the measured blocks from the* Thapsus *amphitheatre is also equal to the Punic cubit (50 cm), or very close to the Roman cubit (45 cm).*

KEYWORDS: MIO-PLIOCENE, TYRRHENIAN, QUARRIES, AMPHITHEATRE, TUNISIA, *THAPSUS*, *THYSDRUS*, PETROGRAPHIC CHARACTERISTICS, GEOTECHNICAL FEATURES, ANCIENT CUBIT

INTRODUCTION

The Roman cities of *Thysdrus* and *Thapsus* are situated in the ancient region of the *Byzacium*, nowadays the Sahil region of Tunisia (Fig. 1). *Thysdrus*, situated inland, has a crossroads role, facilitating trading traffic between the towns located in the western *Byzacium* and the coastal towns situated in the eastern *Byzacium*. *Thapsus* is a harbour town, located between *Leptiminus* in the north and *Gummi* and *Sullecthum* in the south (Fig. 1). The two cities are equipped with amphitheatres. At *Thysdrus*, there are three amphitheatres, and there is just one at *Thapsus*. The third amphitheatre (the Coliseum) and some parts of the second one at *Thysdrus* and the *Thapsus* amphitheatre are built with squared stone blocks (*opus quadratum*).

A few studies have been made concerning the architecture and the function of these monuments (Guerin 1864; Tissot 1888; Lézine 1960; Lachaux 1979; Slim 1984, 1996; Golvin 1988).

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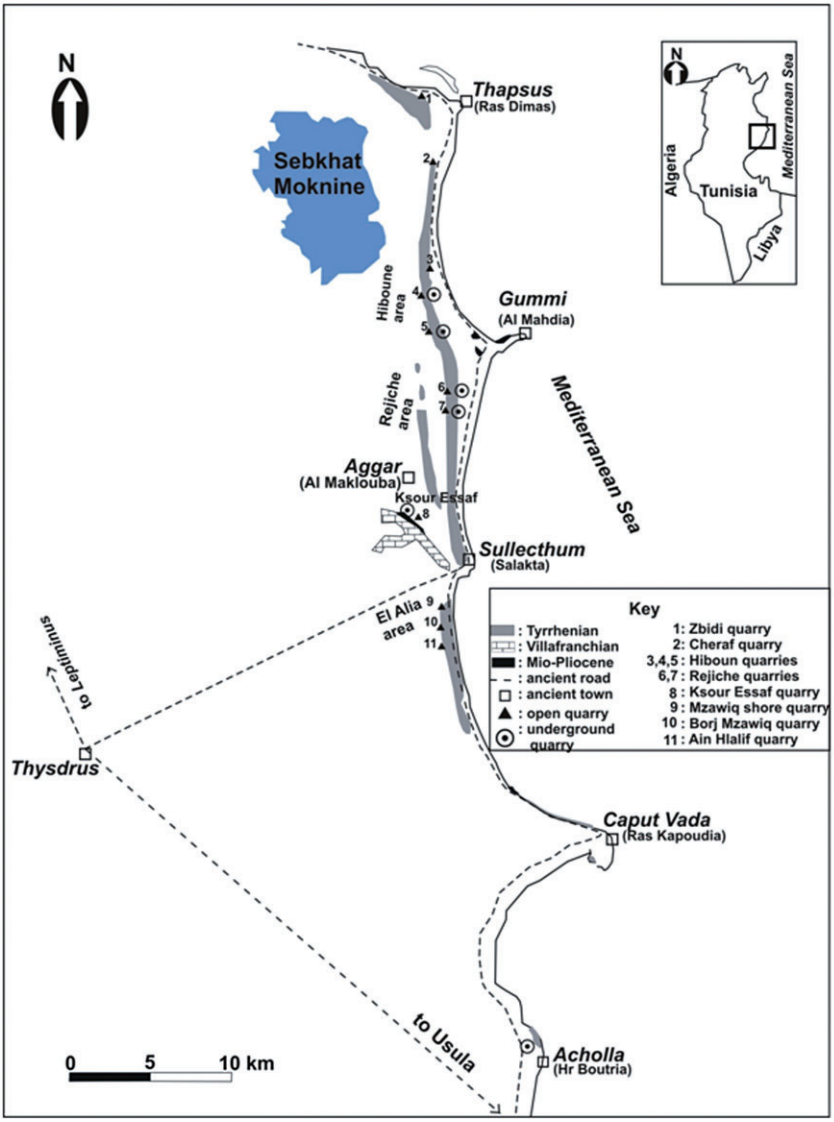

Figure 1 *A map of the ancient quarries and towns.*

Two authors, H. Slim and J.-Cl. Golvin, have indicated that the Coliseum was built using Tyrrhenian blocks (Slim 1984; Golvin 1988). Moreover, the first author has attested that the dimensions of the blocks are equal to the Punic cubit (50 cm) or its multiples (Slim 1984). The second author has pointed out that the heights of the blocks are all equal to the Punic cubit (Golvin 1988). However, the blocks used to build the Coliseum have neither the same origin nor the same sizes. So the question here is to try to discover the origin and determine the sizes of the blocks used in the Coliseum and in the two other amphitheatres at *Thysdrus* and at *Thapsus*. Thus, chemical, petrographic and geotechnical analyses have been carried out on samples from blocks from these amphitheatres and from the quarry stones situated near to the Roman towns. A comparative study between the sizes of the amphitheatre blocks and the cutting marks left on the quarry faces has been undertaken. The results of the analyses reveal the origin of the blocks used to build the amphitheatres and most likely the quarries from which they have been cut.

AMPHITHEATRES: PRESENTATION AND STUDY OF THEIR BLOCKS

Presentation of the amphitheatres

The three amphitheatres at Thysdrus. The first two small amphitheatres are situated east of the ancient urban centre of the Roman town and the third one, which is the largest, is located to the north-east. The first amphitheatre was probably built in the first century AD, on a small calcareous hill of 'Villafranchian' age, which appears at the ground level (Golvin 1988; Slim 1996). The *arena*, which is rounded in shape, was dug into the calcareous limestone rock in the middle of the small hill. Most probably, the steps have not been built using stones, but cut into the rock all around the *arena*. Then, they have been restored with crude bricks because of erosion caused by water run-off (Golvin 1988; Slim 1996).

At the end of the first or at the beginning of the second century, another amphitheatre was built over the first one. The *arena* was filled up to a height of 2.50 m in order to get an elliptical shape. The second *cavea* was constructed above the first one. The compartments (*cunei*) were built using small calcareous rubble stones with a mortar, and filled up with soil. The steps were made of hard-packed soil or crude bricks, covered with a thin layer of plaster (Slim 1996; and see Fig. 2). Segments from the *podium* walls and from other rooms, probably *carceres*, were built using large and medium-sized sandstone blocks (Fig. 3). The number of blocks *in situ* is relatively small. Eight blocks have been measured and their sizes are indicated in Table 1.

One block's length (103 cm) is twice the Punic cubit used at *Lepcis Magna* (51.5 cm) and its height (51 cm) is close to this latter measuring unit (Hallier 1993; and see Table 1). Four blocks

Figure 2 *A view of the second amphitheatre at* Thysdrus.

Figure 3 *Parts of the podium walls and rooms of the second amphitheatre at* Thysdrus.

Table 1 *The sizes of some preserved blocks from the second amphitheatre at* Thysdrus

Length (cm)	*Width (cm)*	*Height (cm)*	*Origin of the blocks**
103	70	51	MP
97	75	47	T
86	70	48	T
70	67	48	T
50	30	15	MP
38	25	11	T
37	28	11	T
28	25	11	T

*MP, Ksour Essaf Mio-Pliocene; T, Rejiche/Al Alya, Tyrrhenian.

have either their length (50 cm) or their width (25 cm, 75 cm) equal to the Punic cubit used at Carthage during the Roman period (50 cm) or its multiples, and two others (70 cm) are close to twice the dimension of the Punic foot (34.3–34.5 cm) (Hallier 1993; and see Table 1).

The small number of preserved blocks is insufficient to assert or invalidate the thesis according to which the builders had either rarely or commonly used blocks cut according to the Punic cubit and the Punic foot. Two samples taken from these blocks have been analysed (see Figs 6 (g) and 7 (c) below).

The Coliseum was probably built towards the end of the first half of the third century (Golvin 1988; Slim 1996). It was constructed on a level surface. It is not only larger than the previous

Figure 4 *A view of the* Thysdrus *Coliseum.*

amphitheatre, but it is considered as the third most important one in the Roman world, after the Coliseum in Rome and the amphitheatre in Carthage. Indeed, the circumference is nearly 427 m and the large axis reaches 148 m, whereas the small one is 122 m. It is composed of a gallery, an *arena*, a *cavea* and a *portico* (Fig. 4; see also Slim 1996). The front has three levels of galleries, decorated with columns. The different parts of the amphitheatre were almost completely constructed using large and medium-sized blocks (*opus quadratum*). As it is very difficult to measure all the building blocks of the amphitheatre now, we chose to measure 1000 blocks located in different parts of the construction. Therefore, as the number of measured blocks is limited, we have chosen to point out only the different blocks' sizes, without mentioning how often they occur.

The different sizes of the measured blocks reveal that they have not been cut only according to the Punic cubit used at Carthage, as has been asserted by some authors (Slim 1984; Golvin 1988). Although most of these blocks show that at least one of their three dimensions (length, width, height) was cut according to the Punic cubit (50 cm) or its multiples (75 cm, 100 cm, 125 cm and 150 cm) (see Table 2), others, which are less numerous, probably have at least one of their three dimensions cut according to the double (103 cm) of the Punic cubit used at *Lepcis Magna*, as in the second amphitheatre (see Table 2), or according to other measuring units that are close to the Punic foot (35 cm) or its multiples (70 cm, 104 cm and 105 cm) and to the Roman foot used in Africa (29.4 cm) or its multiples (30 cm, 60 cm, 90 cm and 120 cm) (see Table 2). Two samples taken from these blocks have been analysed (see Figs 6 (f) and 7 (b) below).

The Thapsus *amphitheatre* This monument is situated south of the Roman town. It was built on a level surface. Nowadays, only the *arena* and a small part of the *podium* and the *cavea* walls are preserved (Fig. 5). The dating of the amphitheatre construction cannot be specified because of the lack of inscriptions and other archaeological materials. Nevertheless, one author has suggested that this monument was built in the second century (Golvin 1988). This amphitheatre is smaller than the *Thysdrus* Coliseum. With regard to the *arena*, the large and the small axes measure 67 m

Table 2 *The dimensions of the measured blocks from the Coliseum*

Location of blocks and columns in the amphitheatre	*Block dimensions*			*Origin of the blocks**
	Length (cm)	*Width (cm)*	*Height (cm)*	
Walls, underground level	103	50	50	MP
	100	73	50	T
	50	50	50	T
	50	40	50	T
Podium walls	105	90	50	MP
	105	75	50	T
	103	75	50	MP
	50	50	50	T
Cavea walls structure	125	70	50	MP
	125	50	50	MP
	120	50	50	T
	110	70	50	MP
	110	50	50	MP
	105	50	50	T
	104	50	50	T
	103	73	50	MP
	100	80	50	T
	100	75	50	MP
	100	60	50	T
	100	50	50	MP and T
	92	75	50	T
	90	75	50	T
	90	70	50	T
	90	50	50	MP and T
	90	50	48	T
	80	55	50	T
	80	50	50	T
	75	55	50	T
	75	50	50	T
	70	70	50	T
	70	50	50	T
	60	50	50	T
	50	50	50	MP and T
Arches	110	70	50	MP
	105	50	50	T
	100	70	50	MP
	100	50	50	MP and T
	95	50	30	T
	90	50	50	T
	80	50	50	T
	75	50	50	T
	70	50	50	MP
	65	54	50	MP
	65	52	50	MP
	60	50	50	MP
	52	50	50	T
	50	50	50	MP and T
	50	50	35	T
	50	50	30	T
	50	30	30	T
		Diameter (cm)		
Columns of the gallery fronts		70		T

*MP, Ksour Essaf Mio-Pliocene; T, Rejiche/Al Alya, Tyrrhenian.

Figure 5 *A view of part of the* Thapsus *amphitheatre.*

× 43 m. However, since the *cavea* is partly destroyed, its axes could not be measured. The *podium* walls and the preserved part of the wall structure that supported the *cavea* were built using large and medium-sized blocks.

As for the *Thysdrus* Coliseum, the blocks used in the preserved walls of the *podium* and in the *cavea* structure in the *Thapsus* amphitheatre had not been cut only according to the Punic cubit used at Carthage. Indeed, most of the measured blocks have a height or a width equal to the Punic cubit (50 cm) or a length corresponding to a multiple of this latter measuring unit (75 cm) (see Table 3). Other blocks, that are less numerous, have a length that is twice the Punic cubit used at *Lepcis Magna* (103 cm), or rather close to the multiples of the Punic foot (70 cm, 104 cm and 105 cm) or the Roman foot (60 cm, 90 cm and 120 cm), and a height (45 cm) that is almost equal to the Roman cubit (44.4 cm) (see Table 3). Three samples taken from these blocks have been analysed (Figs 6 (a), 7 (a) and 7 (d)).

Petrographic and geotechnical analyses

The results of the petrographic and geotechnical analyses carried out on the seven samples reveal that the blocks used to build the *Thapsus* and *Thysdrus* amphitheatres belong to two different geological formations: the Tyrrhenian (Rejiche Formation) and the Mio-Pliocene (Figs 6 and 7). Chemical analyses have not been carried out on the amphitheatre blocks, because the weathered alteration is not important and we expect that there is a slight difference in the chemical analyses.

Tyrrhenian blocks from the amphitheatres According to the petrographic results of the three analysed samples from the *Thapsus* and *Thysdrus* monuments, the blocks are mainly constituted of three kinds of elements (Figs 6 (a), 6 (f) and 6 (g)):

Table 3 *The dimensions of some preserved blocks from the* Thapsus *amphitheatre*

Block location	*Block dimensions*			*Origin of the blocks**
	Length (cm)	*Width (cm)*	*Height (cm)*	
Blocks from the *podium* walls and the *cavea* structure	150	75	50	MP
	140	50	45	T
	125	75	50	T
	120	63	50	MP
	120	50	50	T
	115	50	45	T
	110	70	50	T
	110	50	50	MP and T
	110	50	45	T
	105	50	50	MP and T
	103	80	50	T
	103	50	50	MP and T
	100	85	50	MP
	100	64	50	MP
	100	62	50	MP
	100	59	50	MP
	100	57	50	MP
	100	54	50	MP
	100	50	50	MP and T
	90	75	50	MP
	90	55	45	T
	90	50	50	MP and T
	80	60	45	MP
	75	60	50	T
	70	50	50	MP
	65	50	50	T
	50	50	45	T

*MP, Ksour Essaf, Mio-Pliocene; T, Rejiche/Al Alya/*Thapsus*, Tyrrhenian.

• skeletal elements consisting of bioclasts of lamellibranches, echinoderms, foraminifera and algae;
• non-skeletal elements, which consist of quartz grains, scarce oolites and carbonated pellets; and
• the cement of the whole constituents, which consists of micrite or/and microspar.

The petrographic texture is grainstone to packstone. These samples show an important porosity that is intergranular, and scarcely intragranular. The former results from the weathering and it is well marked on the exterior parts of the amphitheatres. This petrographic analysis of the amphitheatre Tyrrhenian blocks reveals that these samples consist of limestone.

Mio-Pliocene blocks from the amphitheatres The petrographic analysis carried out on the four samples taken from the *Thapsus* and *Thysdrus* amphitheatres (Figs 7 (a)–7 (d)) shows a biomicritic oolitic limestone containing skeletal elements consisting of bioclasts of lamellibranches. The main phase is dominated by orthochemical elements that are oolites, the core of which is constituted either by a quartz grain or by microsparite. The cement is principally composed of

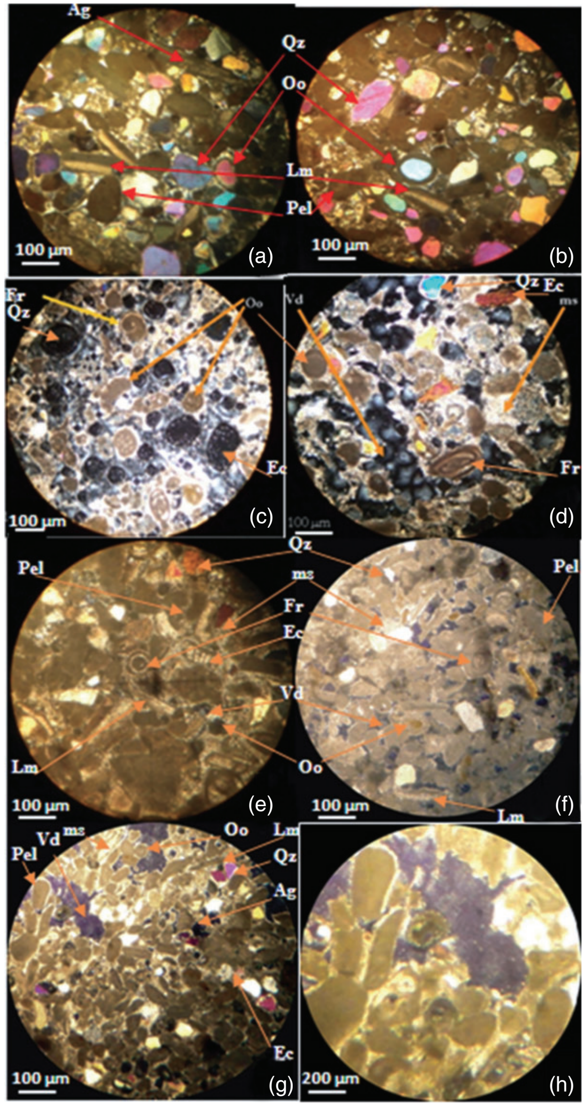

Figure 6 *Thin sections of Tyrrhenian samples from amphitheatres and quarries. (a) A thin section of a sample block from the* Thapsus *amphitheatre (the thin section shows a limestone with abundant bioclasts, which can be seen both in long section and transverse section; the long straightened shells are lamellibranch fragments). (b) A thin section of a sample stone from the Zbidi quarry (the materials include pellets and oolites, as well as various skeletal fragments, especially bivalves). (c) A thin section of a sample stone from the Cheraf quarry (foraminifera shell, echinoderm plates, quartz and other mollusc fragments, surrounded by dark lime mud and important intergranular porosity). (d) A thin section of a sample stone from the Rejiche quarry (foraminifera shell, echinoderm plates, quartz and other mollusc fragments, surrounded by dark lime mud and important intergranular porosity). (e) A thin section of a sample stone from the Borj Mzawiq quarry (this thin section shows a limestone constituted by ooliths, pellets, quartz and skeletal elements: foraminifera, lamellibranchs and echinoderms). (f) A thin section of a sample block from the* Thysdrus *Coliseum (this thin section shows the same constituents as the quarry sample, but it contains some intergranular voids). (g) A thin section of a sample block from the second amphitheatre at* Thysdrus *(same remark as indicated in (f), but this image shows abundant pellets). (h) A detail of (g), showing porosity resulting from alteration by meteoric water. Key: Ag, algae; Ec, echinoderm; Fr, foraminifera; Lm, lamellibranches; Oo, ooid; Pel, pellet; ms, microspar; Qz, quartz; Vd, void.*

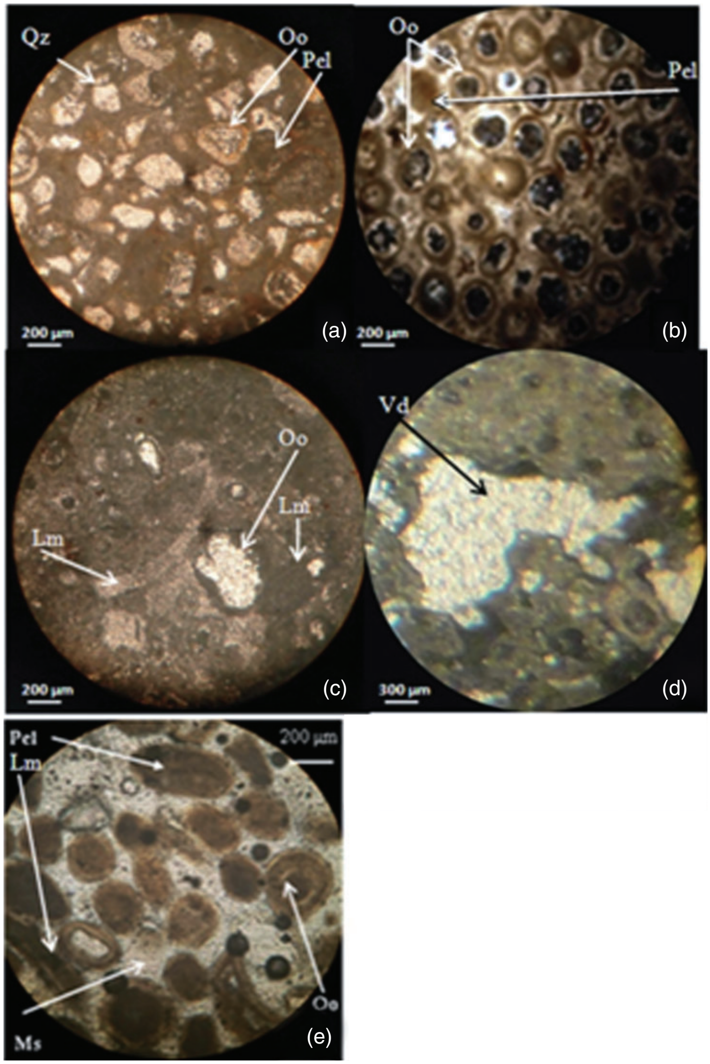

Figure 7 *Thin sections of Mio-Pliocene samples from amphitheatres and a quarry. (a) A thin section of a Mio-Pliocene sample block from the* Thapsus *amphitheatre. (b) A thin section of a Mio-Pliocene sample block from the* Thysdrus *Coliseum. (c) A thin section of a Mio-Pliocene sample bloc from the second* Thysdrus *amphitheatre. (d) A thin section of a Mio-Pliocene sample block from the* Thapsus *amphitheatre, showing alteration manifested by vacuolar voids. (e) A thin section of a sample stone from Ksour Essaf quarry (oolitic peloidal sediment in which much of depositional space between grains is unfilled by cement—the microfacies shows intergranular porosity). Key: Lm, lamellibranches; Oo, ooid; Pel, pellet; ms, microspar; Qz, quartz; Vd, void.*

micrite and sometimes by microsparite (Figs 7 (a)–7 (c)). The texture is grainstone and the porosity is essentially intergranular. However, the former is very important at the exposed parts of the amphitheatres, which are weathered, and dissolution of carbonate minerals could be clearly distinguished (Fig. 7 (d)). The Mio-Pliocene microfacies is more resistant to weathering processes compared to the Tyrrhenian ones.

Table 4 *Geotechnical analyses of samples taken from the amphitheatres*

	Density	*Capillarity coefficient after 1 h*	*Water mass benefit after 24 h (g)*	*Porosity (%)*	*Resistance to simple strength (MPa)*
Tyrrhenian limestone blocks from the *Thapsus* and *Thysdrus* amphitheatres	1.41–1.86	2.21–2.36	25–32	15–39	0.0–5.2
Mio-Pliocene limestone blocks from the *Thapsus* and *Thysdrus* amphitheatres	1.7–1.9	0.28–0.32	16.4–18.4	8.7	12.5–13.5

Table 5 *Chemical analyses of the samples from the quarries*

	% CaO	*% SiO_2*	*%MgO*	*%Al_2O_3*	*%Fe_2O_3*	*%L.O.I.(Loss on Ignition)*	*Total*
Limestone blocks from Al Alya and *Thapsus* Tyrrhenian quarries	37	26	0.5	1	0.4	32	96.9
Limestone blocks from Ksour Essaf quarries (Mio-Pliocene)	52	2.5	0.5	0.5	0.3	42.3	98.1

Geotechnical features In order to ascertain the geotechnical features of the Mio-Pliocene and Tyrrhenian limestone blocks, the following tests have been carried out: density, capillarity coefficient, porosity and resistance to simple compressive strength. The comparative study between the two different kinds of blocks attests that the Mio-Pliocene limestone blocks are less porous and more resistant than the Tyrrhenian ones (see Table 4).

QUARRIES FROM WHICH STONE BLOCKS WERE EXTRACTED

One Mio-Pliocene quarry has been identified on the hill of Ksour Essaf known as Hamadet Alhadida, and 10 Tyrrhenian quarries have been found in the area between *Thapsus* and Al Alya (Fig. 1). Other ancient quarries may have existed on the Tyrrhenian dune line, but they have been destroyed following modern exploitation in this area. One sample has been taken from the Mio-Pliocene quarry faces situated on the hill of Ksour Essaf (Figs 1 and 7 (e)). Four other samples have been cut from the Tyrrhenian quarry faces located in the Al Alya and Rejiche areas (Borj Mzawiq and Rejiche quarries), near the *Thysdrus* amphitheatres, and in the neighbourhood of the *Thapsus* amphitheatre (Cheraf and Zbidi quarries; see Figs 1 and 6 (b)–6 (e)). Petrographic and geotechnical analyses have been carried out on these samples.

Description of the analyses

Chemical analyses The Mio-Pliocene blocks are rich in CaO and the Tyrrhenian blocks from *Thapsus* and the Al Alya quarries are the most siliceous (see Table 5).

Petrographic analyses by optical microscopy

• *Tyrrhenian blocks from the quarries of Al Alya, Rejiche and* Thapsus. Petrographic analyses show that the constituents found in the blocks from the quarries and in the amphitheatre blocks are the same, but dissolution of carbonated elements can be clearly distinguished (Figs 6 (b)–6 (e)). This is confirmed by the calcimetry results, which show a decrease in the percentage of $CaCO_3$, from 66% (quarry samples) to 61% (amphitheatre block samples).

• *Mio-Pliocene blocks*. The petrographic analyses show the same allochems and cement found in the block from the quarry and in the amphitheatre blocks, but dissolution of carbonated elements is relatively less important than in the case of the Tyrrhenian blocks (Fig. 7 (e)). The percentage of $CaCO_3$ decreases from 93% (quarry sample) to 90% (amphitheatre block samples).

Geotechnical features The results of the geotechnical analyses show, as do the previous ones, that the Tyrrhenian stones are more porous and less resistant than the Mio-Pliocene stones (see Table 6).

The Tyrrhenian quarries located between Thapsus *and Al Alya*

A comparative study between the Thapsus *quarry stones and the* Thapsus *amphitheatre Tyrrhenian blocks* In the area of *Thapsus*, two quarries have been identified. The first one is located at Cheraf, nearly 3.7 km SSW of the Roman port, and the second is situated at Zbidi, nearly 3.5 km west of this port. Nowadays, the Cheraf quarry is better preserved than the Zbidi one, because the latter has been mainly covered with soil and used for new buildings (Figs 8 (a)–8 (c)). The comparative study of the petrographic and geotechnical analyses between the Tyrrhenian blocks used to build the amphitheatre and the two samples cut from these quarries shows that the blocks have most probably been extracted from the two quarries. The cutting marks left on the quarry faces are not only valuable evidence of the quarrying technique used by the quarry workers to cut stones, but they also give us an idea about the sizes of some extracted blocks. The technique for

Table 6 *Geotechnical analyses of the samples from the quarries*

	Density	*Capillarity coefficient after 1 h*	*Water mass benefit after 24 h in g*	*Porosity in %*	*Resistance to simple strength in MPa*
Limestone blocks from Al Alya and *Thapsus* Tyrrhenian quarries	2.06 to 2.24	2.42 to 2.52	38 to 41	13.9 to 15.3	4 to 5.2
Limestone blocks from Ksour Essaf Mio-Pliocene quarry	2.4	0.30 to 0. 38	18.3 to 19.7	5 to 9	12.5 to 14

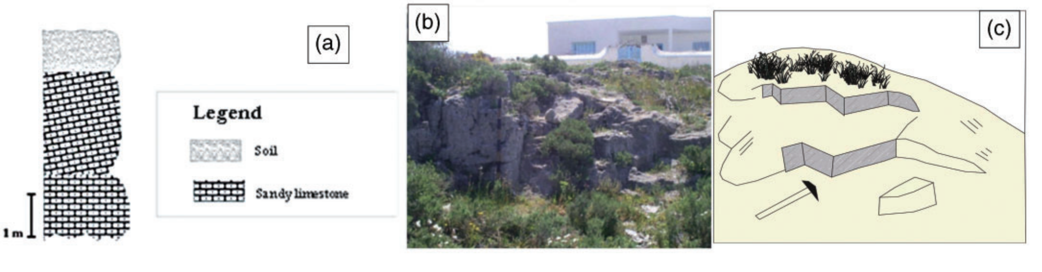

Figure 8 *The Cheraf quarry: (a) a geological section; (b) a general view; (c) a block diagram.*

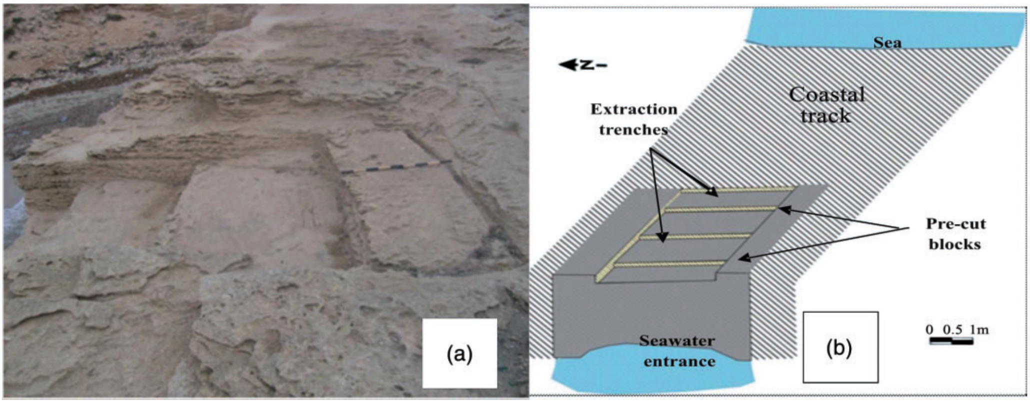

Figure 9 *The Borj Mzawiq quarry: (a) part of the eastern face of the quarry, showing pre-cut blocks; (b) a block diagram.*

cutting blocks from these quarries has been studied in a previous paper (Younès and Ouaja 2008). Here is a summary of a few of the stages of this technique. The quarry workers take off the thin bad layer of the stone that is useless for building purposes. Then they outline the block to be cut by following the natural planes of weakness (joints and stratigraphic levels)—when they are visible on the quarry faces, which is not the case here. After that, using picks or another cutting edge tool, the 'escoude', they make cutting trenches on only three sides of the block, because the other side has already been isolated. Afterwards, on the lower horizontal side, they make a fracture line and some holes in order to insert the metallic wedges that they hammer so as to definitively cut the block. This technique for cutting blocks is known from other ancient quarries in the Mediterranean area (Dworakowska 1983; Bessac 1991; Goette *et al*. 1999; Hayward 1999; Storemyr *et al*. 2006; Younès and Ouaja 2009; Gutierrez Garcia-Moreno 2009; Gaied *et al*. 2010).

The cutting marks left on the quarry faces show that the extracted blocks are medium and small-sized. Some blocks were cut according to the Punic cubit used at Carthage (50 cm) or its multiples (75 cm and 25 cm), or close to the Roman cubit (45 cm), the Punic foot (35 cm) and its double (70 cm), and the Roman foot (30 cm) and its double (60 cm) (see Table 7, Zbidi and Cheraf quarries). The comparative study between the sizes of blocks employed in the preserved amphitheatre walls and the sizes of cutting marks left on the quarries shows that they are different. They must have been cut before the end of exploitation of the quarries.

A comparative study between the Al Alya quarry stones and the Thysdrus *amphitheatre Tyrrhenian blocks* Three quarries have been identified in the area of Al Alya, which is almost 30 km east of *Thysdrus* (Fig. 1). The comparative study of the petrographic and geotechnical analyses between the Tyrrhenian blocks used to build the two *Thysdrus* amphitheatres and the sample taken from the Borj Mzawik quarry attests that the blocks employed in the amphitheatres may have come from the Al Alya quarries. Block cutting marks left on the quarry faces are not well preserved, but they give us some indications about the sizes of some cut blocks. Indeed, the blocks extracted from the Borj Mzawiq quarry are large and medium-sized (Figs 9 (a) and 9 (b)).

According to the block marks left on these quarry faces after extraction, the quarry workers had cut blocks according to the Punic cubit used at Carthage (50 cm) and its multiples (150 cm,

Table 7 *The dimensions of some preserved blocks from quarries*

Zbidi quarry: block dimensions measured in 1993, when the quarry was better preserved			*Cheraf quarry: block dimensions measured in 1993 and 2009*			*Mzawiq shore quarry: block dimensions measured in 2005 and 2009*			*Borj Mzawiq quarry: block dimensions measured in 2005 and 2009*			*Ayn Hlalif and Ayn Smarra quarries: block dimensions measured in 2005 and 2009*			*Ksour Essaf quarry*		
Length (cm)	*Width (cm)*	*Height (cm)*	*Length (cm)*	*Width (cm)*	*Height (cm)*	*Length (cm)*	*Width (cm)*	*Height (cm)*	*Length (cm)*	*Width (cm)*	*Height (cm)*	*Length (cm)*	*Width (cm)*	*Height (cm)*	*Length (cm)*	*Width (cm)*	*Height (cm)*
75	50	50	70	50	50	70	70	50	245	140	25	150	50	50	155	150	91
70	50	50	70	50	45	70	50	50	245	90	25	140	50	45	145	90	91
65	50	50	60	50	30	70	50	25	120	40	40	110	70	50	120	65	91
60	40	25	60	50	25	70	40	25	90	60	50	100	50	50	115	85	65
50	50	50	50	50	50	60	50	25	90	50	50	100	50	45	115	92	90
50	50	25	50	25	25	60	40	25	80	50	25	100	40	40	–	–	–
50	30	25	40	25	25	50	30	25	70	60	50	80	30	25	–	–	–
40	25	25	30	25	15	–	–	–	60	50	20	70	35	35	–	–	–
35	25	15	–	–	–	–	–	–	60	50	20	70	35	35	–	–	–
–	–	–	–	–	–	–	–	–	35	15	35	60	40	50	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	50	45	20	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	35	25	15	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	25	20	10	–	–	–

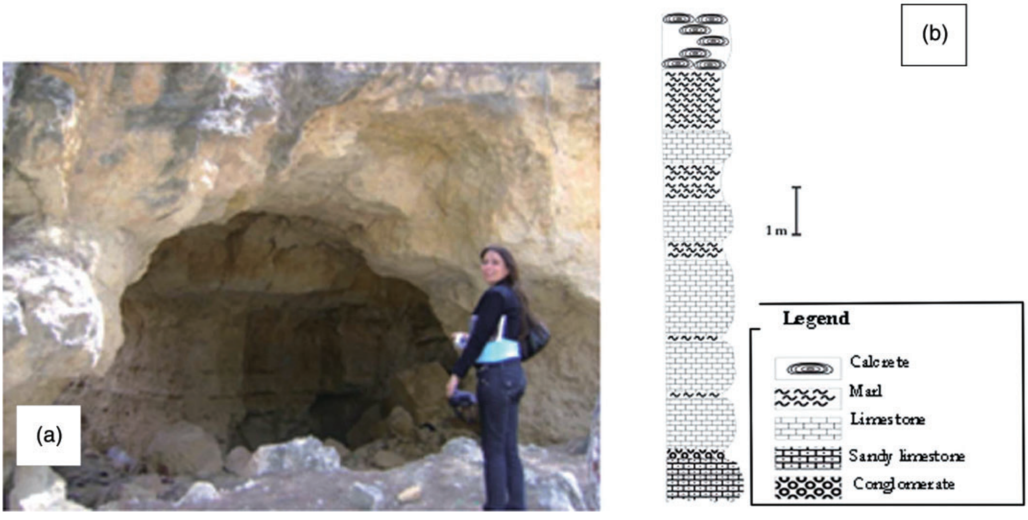

Figure 10 *The Ksour Essaf quarry: (a) a view of one gallery from the quarry; (b) a geological section.*

100 cm and 25 cm), or close to the Roman cubit (45 cm), the Punic foot (35 cm), the Roman foot (30 cm) and their doubles (70 cm/60 cm), as at the Zbidi and Cheraf quarries (see Table 7, Mzawiq shore, Borj Mzawiq, Ayn Hlalif and Ayn Smarra quarries).

The sizes of blocks used to build the third amphitheatre at *Thysdrus* and the sizes of the last blocks cut from the Al Alya quarries differ in most cases. It is possible that the *Thysdrus* amphitheatre blocks had been extracted from the Al Alya quarries before the end of exploitation of the quarry, or from other ancient quarries situated in the Rejiche area that have since been destroyed by modern extraction (Fig. 1).

The Mio-Pliocene quarry A large unknown ancient quarry has been identified on the hill of Ksour Essaf, at an altitude of 70 m. This area is known, by the inhabitants of the village, by the name Hamadet Alhadida and is planted with trees, as for the quarries at Al Alya (Fig. 1). The quarry is located nearly 28 km north-east of *Thysdrus* and 24 km south of *Thapsus*. Nowadays, this quarry is—in places—well preserved (Fig. 10 (a)). The quarry workers began to cut blocks in the open air and then they continued exploitation in galleries because of the thick pumice stone layer made of calcrete and marl (Fig. 10 (b)). The marl layers between the limestone strata become thicker while progressing from the sides to the middle of the hill. For this reason, extraction was done in small and medium-sized galleries around the hill. Seven galleries have been noted on the northern and eastern sides of the hill.

The ceiling of the medium galleries is supported by a turned pillar, as in the other ancient quarries known in the Tyrrhenian dune line (Younès and Ouaja 2009). The quarry workers exploited the natural fissures in order to determine the sizes of the blocks to be cut. That is why a few block cutting marks are still visible on the gallery faces. They give us a few indications about the sizes of extracted blocks. Indeed, they are large-sized (see Table 7, Ksour Essaf quarry). The preserved marks left on the quarry faces show that the sizes of the cut blocks are different from the sizes of the blocks used in the two amphitheatres at *Thapsus* and *Thysdrus*. Most probably, the quarry workers have extracted large-sized blocks from the quarries by following the natural fissures. Then, these blocks have been cut up into small, medium and large-sized ones ready to be used in the construction of the amphitheatres.

CONCLUSIONS

The petrographic and geotechnical analyses show that the amphitheatres were built using both Tyrrhenian and Mio-Pliocene limestone blocks. The Mio-Pliocene limestone blocks are less porous and more resistant than the Tyrrhenian ones. Nowadays, it is difficult to know if the number of Tyrrhenian limestone blocks used in the three amphitheatres is greater than for the Mio-Pliocene ones, because the monument structures are not completely preserved. Nevertheless, according to the larger number of ancient Tyrrhenian quarries found between Hiboun and Al Alya compared to the sole ancient Mio-Pliocene quarry identified at Ksour Essaf, the builders are likely to have used more Tyrrhenian limestone blocks than Mio-Pliocene ones for building the three amphitheatres.

The study of the block sizes has revealed that the height of almost all the measured blocks from the Coliseum is equal to the Punic cubit used at Carthage, and that the height of the measured blocks from the *Thapsus* amphitheatre also corresponds to the Punic cubit or is very close to the Roman cubit. This study also shows that the length and/or the width of some blocks from both amphitheatres at *Thysdrus* and from the one at *Thapsus* correspond to multiples of the Punic cubit, or are very close to the Punic and the Roman feet and their multiples.

The block cutting marks identified on the Tyrrhenian quarry faces attest that for extracting blocks, the quarry workers used the Punic cubit that was employed at Carthage and its multiples, or measuring units close to the Roman cubit, or to the Punic and Roman feet and their multiples. Yet, the comparison made between the sizes of the measured blocks from the Coliseum and from the *Thapsus* amphitheatre, and the sizes of the blocks whose cutting marks are still visible on the quarry faces shows that a great number of blocks do not have the same dimensions. The Tyrrhenian limestone blocks used in the *Thapsus* amphitheatre and in the Coliseum must have been cut before the end of exploitation of the quarries.

With regard to the Mio-Pliocene limestone blocks, the size difference between the rare visible cutting marks left on the quarry faces and the sizes of the blocks used in both amphitheatres may be explained by the fact that large-sized stone blocks have been extracted by the quarry workers, who followed the rock natural fissures. Then, these large-sized blocks have been cut into small, medium and large-sized ones, ready to be used in these monuments.

REFERENCES

Bessac, J.-Cl., 1991, Etude d'un outil d'extraction: l'escoude, in *Carrières et construction en France et dans les pays limitrophes*, 93–104, CTHS, Paris.

Dworakowska, A., 1983, *Quarries in Roman provinces*, Polish Academy of Sciences, Institute of the History of Material Culture, Warsaw, Poland.

Gaied, M. E., Younès, A., and Gallala, W., 2010, A geoarchaeological study of the ancient quarries of Sidi Ghedamsi Island (Monastir, Tunisia), *Archaeometry*, **52**, 531–49.

Goette, H. R., Polikreti, K., Vacoulis, T., and Maniantis, Y., 1999, Investigation of the greyish-blue marble of Pentelikon and Hymettus, in *Archéomatériaux: marbres et autres roches: actes de la IVe Conférence internationale de l'Association pour l'étude des marbres et autres roches utilisés dans le passé, ASMOSIA IV, Bordeaux, Talence, 9–13 October 1995* (ed. M. Schvoerer), 83–90, Presses universitaires de Bordeaux/Centre de recherche en physique appliquée à l'archéologie, Talence.

Golvin, J.-Cl., 1988, *L'amphithéâtre romain: essai sur la théorisation de sa forme et de ses fonctions*, tome 1, texte, CNRS, De Boccard, Paris.

Guerin, V., 1864, *Voyage archéologique dans la Régence de Tunis*, Henri Plon, imprimeur-éditeur, Paris.

Gutierrez Garcia-Moreno, A., 2009, *Roman quarries in the northeast of Hispania (modern Catalonia)*, Documenta 10, Institut Català d'Arqueologia Clàssica Tarragona.

Hallier, G., 1993, Coudée, in *Encyclopédie berbère, XIV*, paragraphs 2112 and 2116, Edisud, Aix-en-Provence.

Hayward, C. L., 1999, First results from high resolution study of ancient construction stone quarries of the Corinthia, southern Greece, in *Archéomatériaux: marbres et autres roches: actes de la IVè Conférence internationale de l'Association pour l'étude des marbres et autres roches utilisés dans le passé, ASMOSIA IV, Bordeaux, Talence, 9–13 October 1995* (ed. M. Schvoerer), 91–9, Presses universitaires de Bordeaux/Centre de recherche en physique appliquée à l'archéologie, Talence.

Lachaux, J.-Cl., 1979, *Théâtres et amphithéâtres d'Afrique Proconsulaire*, Edisud, Aix-en-Provence.

Lézine, A., 1960, Notes sur l'amphithéâtre de *Thysdrus*, *Cahiers de Tunisie*, **31**, 29–50.

Slim, H., 1984, Recherches préliminaires sur les amphithéâtres romains de Tunisie, in *Africa Romana, Atti del I convegno di studio, Sassari, 16–17 dicembre 1983*, 148–58, Edizioni Gallizzi, Sassari.

Slim, H., 1996, *El Jem*, *l'antique* Thysdrus, Alif-Les éditions de la Méditerranée, Tunis.

Storemyr, P., Heldal, T., and Bloxam, E., 2006, QuarryScapes: conservation of ancient stone quarry landscapes in the Eastern Mediterranean, in *Society for American Archaeology, 71st Annual Meeting, April 26–April 30, San Juan, Puerto Rico*, 117–32, Society for American Archaeology (SAA) Editions.

Tissot, Ch., 1888, *Géographie comparée de la province romaine d'Afrique*, tome 2, 184–7, Hachette, Paris.

Younès, A., and Ouaja, M., 2008, Les carrières antiques en Byzacène entre *Sullecthum* et Ruspina, *Notes du service géologique de Tunisie*, no. 76, 55–82, Editions du Service Géologique de Tunis, Tunis.

Younès, A., and Ouaja, M., 2009, The ancient underground quarries between Sullecthum and Leptiminus, in *Leukos lithos: marbres et autres roches de la Méditerranée antique: études interdisciplinaires, Actes du VIIIè colloque international de l'Association for the study of Marble and Other Stones used in Antiquity (ASMOSIA), Aix-en-Provence, 12–18 June 2006* (ed. Ph. Jockey), 229–37 and plates 14 and 15, Maisonneuve & Larose/Maison méditerranéenne des Sciences de l'Homme, Paris.