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The Evolution of grinding tools in the Lez Valley (La Cougourlude and Lattara) from the 6th to the 4th Centuries BC (Hérault, France)

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THE EVOLUTION OF MILLING TOOLS IN THE LEZ RIVER VALLEY (LA COUGOURLUDE AND LATTARA) FROM THE 6TH TO THE 4TH CENTURIES BC (HÉRAULT, FRANCE)

INTRODUCTION

The study area

The Lez River Valley runs roughly from north to south through Languedoc's coastal plain to the east of Montpellier. The Late Bronze Age *oppidum* of *Sextantio* at the foot of the first limestone massifs a few kilometres inland is this valley's first major Protohistoric occupation. This hinterland settlement then gave way in the Early Iron Age to a series of small rural villages and larger grouped, fortified sites, notably the coastal settlements of La Cougourlude and ultimately *Lattara* (Fig. 1). This study focuses on the large assemblages of querns driven

with a to and fro motion (aka saddle querns) of these two coastal sites.

Both La Cougourlude and *Lattara* have been the object of extensive archaeological operations. *Lattara*, identified by Henri Prades in 1963, has benefitted from a CNRS research project comprising regular programmed excavations throughout the last 30 years supervised by Michel Py, Thierry Janin, Pierre Garmy and Eric Gailledrat, and Gaël Piques. The important link between La Cougourlude and *Lattara* was identified in 2007 during a rescue excavation at La Cougourlude led by Isabelle Daveau. In fact, the two sites, about one kilometre apart, overlapped for a few decades (Fig. 2). Together they span the whole chronological sequence of the Iron Age.

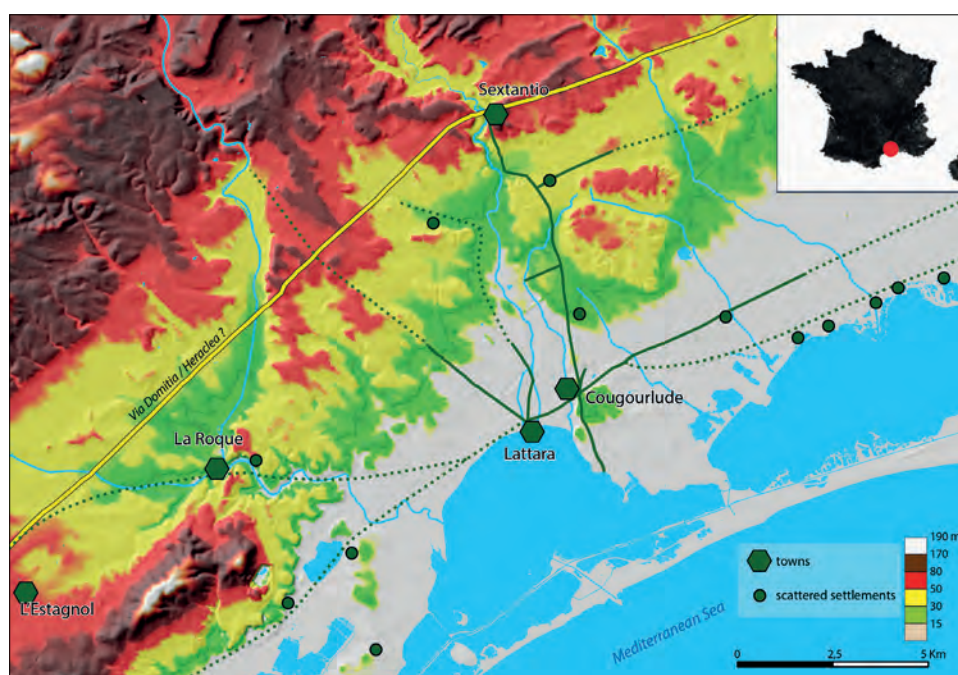


Fig. 1. Map of the settlements and roads in the region of Lattes (France) in the 6th-5th century BC (CAD: I. Daveau, DEM source: RGEalti IGN).

LA COUGOURLUDE

La Cougourlude stretches over both banks of the Lironde River a few hundred metres from the mouth of an ancient coastal lagoon (Daveau *et al.* 2015; Daveau & Py 2015). This point corresponds to the intersection of a road running along the coastline that connected the coastal area with the hinterland and the *oppidum* of *Sextantio* cited above.

After a series of intermittent occupations throughout the end of the Bronze Age and the beginning of the Early Iron Age, La Cougourlude became a permanent fixture at the outset of the 6th century BC and experienced a sudden and spectacular rise reaching its largest extension at the turn of the 6th-5th centuries. Its sector on a hill was encircled by a rampart before the city extended to the plain to each side of the river eventually occupying a total surface of about 30 hectares (Fig. 3). La Cougourlude's expansion provoked the abandonment of the surrounding villages as their populations were drawn to the large site. Its emergence was accompanied by a development of a number of features in the surrounding territory such as a network of roads, monumental tombs and places of worship.

The great proportion of imported ceramic ware at La Cougourlude, much greater than that of other contemporary settlements, reflects the site's early and intense role in the framework of Mediterranean commercial networks (Fig. 4). Despite its rising prosperity and constant contact with Mediterranean traders, La Cougourlude offers few indications of acculturation except for the consumption of foreign wine. Throughout its occupation it retained, for example, its urban plan and traditional features. The earth and wood houses remained dispersed and the city never adopted a regular urban layout such as that known since the 6th century BC in the area of Marseille about 100 km away. Although pottery imports consisted mainly of amphorae and tableware (Fig. 5), the repertoire of domestic forms remained stable suggesting the preservation of traditional culinary practices.

La Cougourlude was in fact a strategic point of entry, exchange and consumption of Mediterranean goods, foreshadowing the role subsequently assumed by *Lattara* after its founding around 500 BC. The two sites, very close yet very different in appearance, coexisted for a few decades before La Cougourlude was deserted towards 475 BC at the peak of its prosperity. Moreover, there is no evidence of a catastrophic end in the form of a flood, fire or bellicose destruction. Its only

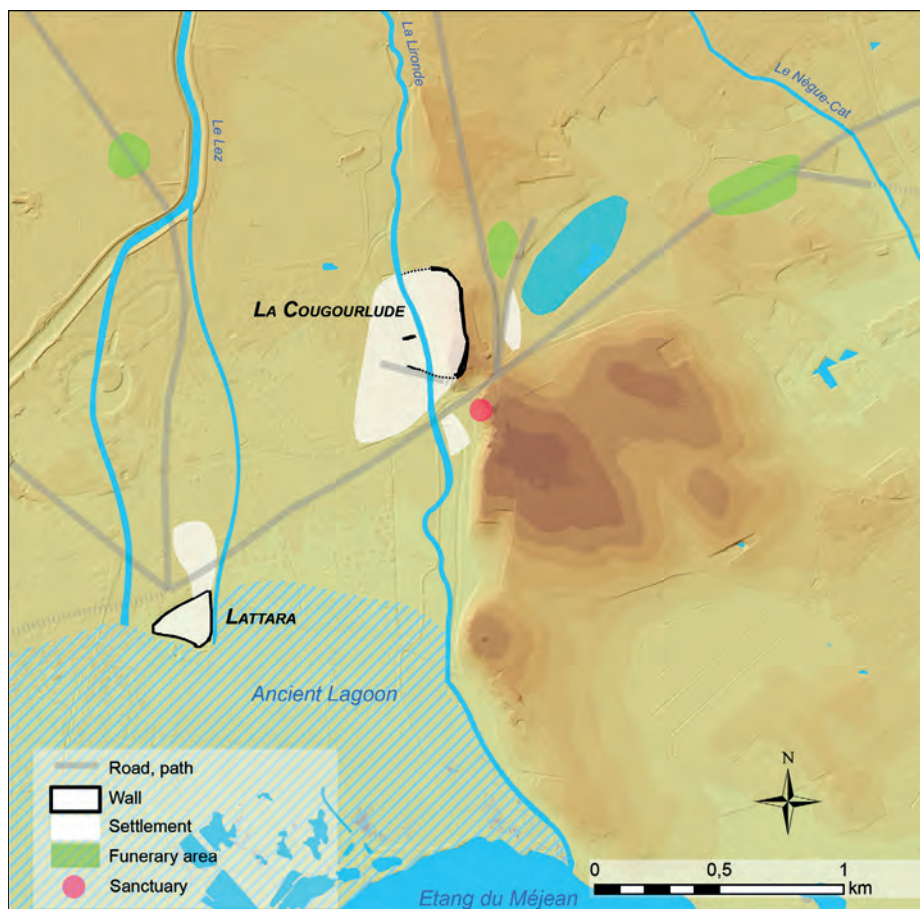


Fig. 2. The Lower Lez Valley around 500 BC (CAD: I. Daveau, DEM source: RGEalti IGN).

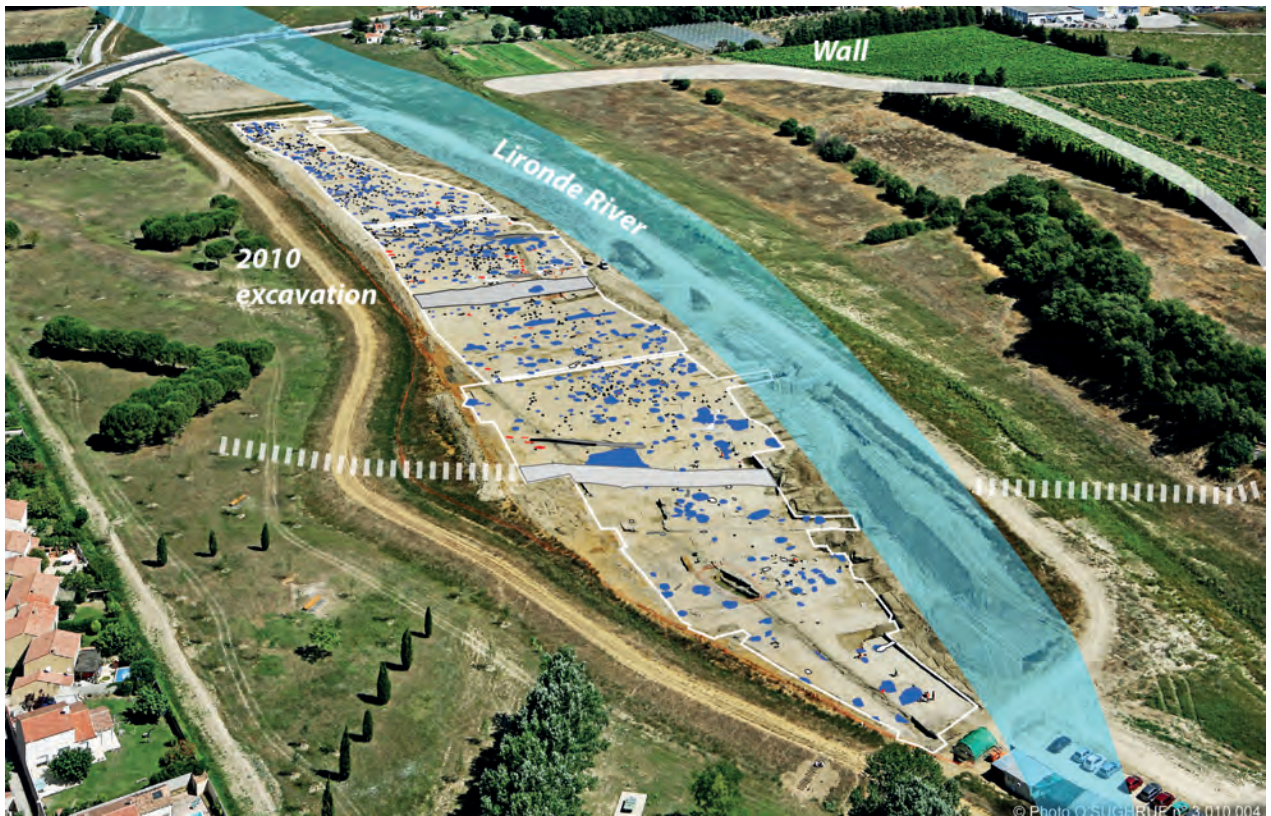


Fig. 3. View of the preventive excavations (3 ha) carried out in 2010 at Cougourlude. The archaeological work carried out in 2016 on the opposite bank of the canal revealed the extension of the site and the presence of a fortified enclosure (Photo: Cl. O'Sughrue, CAD: I. Daveau).

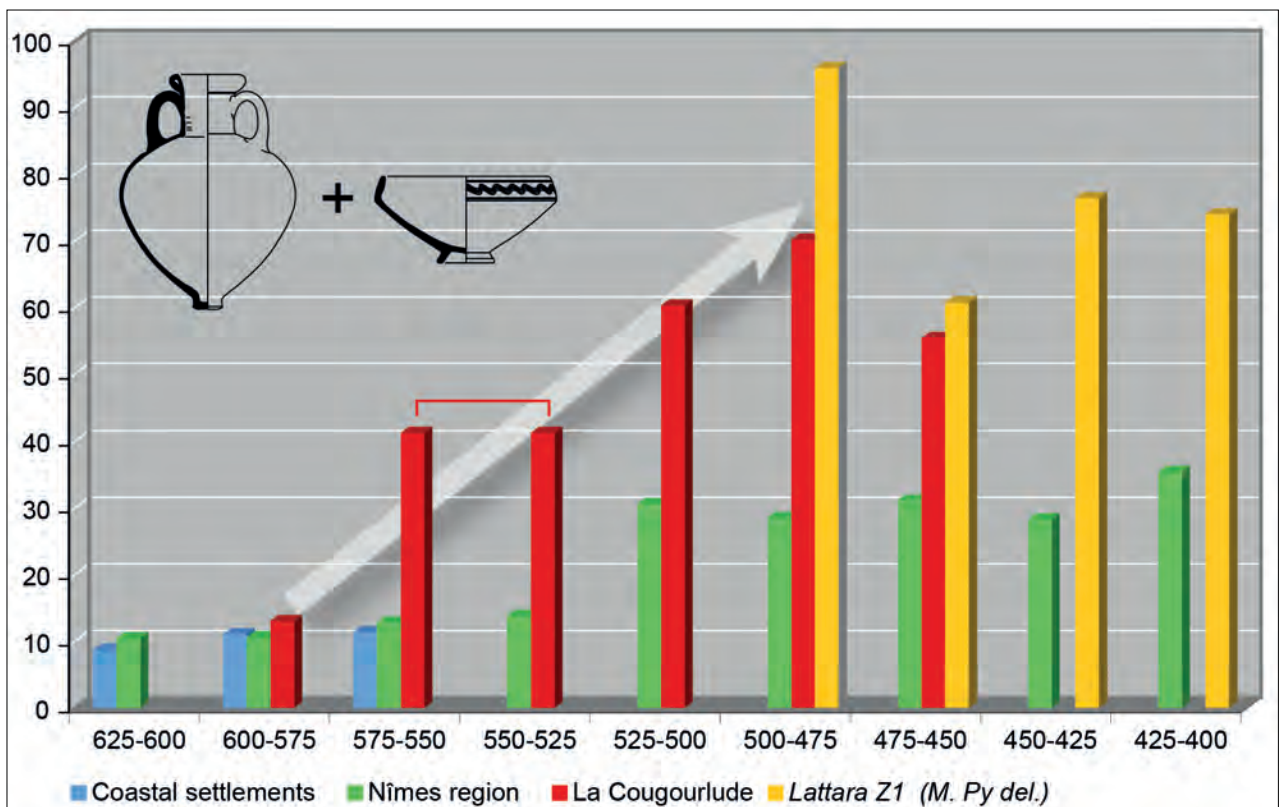


Fig. 4. Evolution of the percentage of imported pottery (amphorae and tableware) at the sites of the region from 625 to 400 BC (CAD: M. Py).

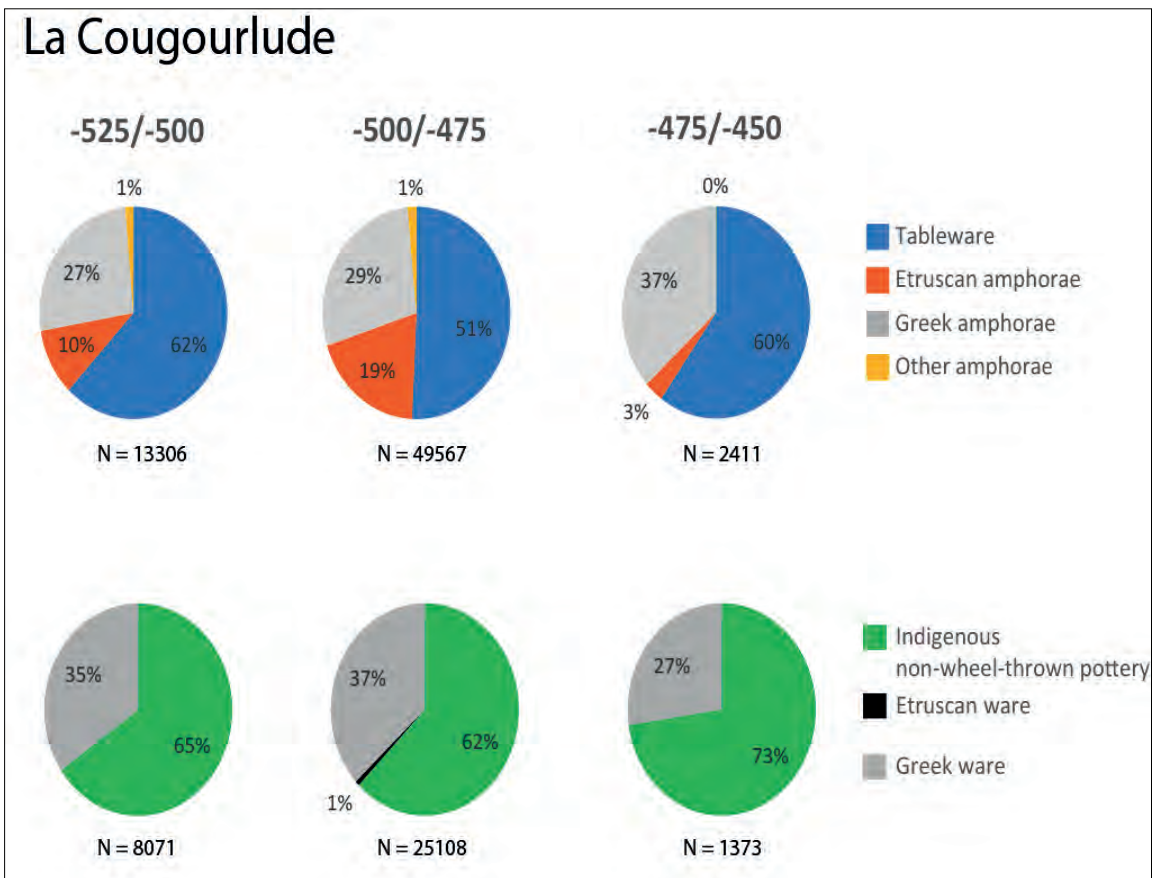


Fig. 5. Evolution of the composition of the pottery assemblages at La Cougourlude between the end of the 6th and the middle of the 5th century BC. Top, amphorae and tableware; bottom: nature of the vessels.

features surviving until the middle of the 5th century BC were a few modest peripheral domestic nuclei.

LATTARA

The site of Lattes/St-Sauveur was formally identified as ancient *Lattara* in the anonymous *Ravenna Cosmography* penned in the 7th century AD. The settlement is on a narrow sand embankment advancing into the lagoon probably formed by two branches of the Lez. The evolution of the landscape was directly linked to the progradation of the Lez Delta since the Iron Age resulting in the gradual silting of the lagoon (Janin & Py 2008; Py 2009).

Extensive excavations indicate *Lattara* occupied all of the available space. The boundaries of its “heart” encircled by a rampart correspond to an area of about 3.5 hectares (Fig. 6). Its best known phase of urban planning line up with the end of the Iron Age. Only two modest archaeological exploratory sectors (zones 1 and 27) were sunk deep into its earliest stratigraphic sequences. These “windows” offer a glimpse of the foundational levels around 500 BC. Observations of these

early phases remain nonetheless poor as their excavation is complicated by their depth (up to 4 m) and the constant penetration of groundwater.

The oldest levels of *Lattara* resting directly on the sterile substrate correspond to the outset of the 5th century BC. Yet sporadic earlier finds leave open the possibility of an older phase contemporary to La Cougourlude. Although this hypothetical older and smaller settlement (possibly occupying the headland) cannot currently be confirmed, it could have served as the point of arrival of imported Mediterranean products unearthed at both La Cougourlude and other sites of the hinterland.

Despite the dissimilarities of the finds from zones 1 and 27, these two “windows” into the site’s older levels leave no doubt as to the existence of a large Etruscan community (Lebeauupin 2014; Gailledrat & Vacheret 2020). Moreover, there is even evidence of a deliberate planning or surveying of the space, a sort of early cadastration preceding an orthonormal urban outline or design correlated to the layout of the rampart. Construction no doubt spanned several years and certain quarters were still being raised at the time of a brutal and thorough destruction of this early occupation around 475 BC (Garmy & Gailledrat 2015).

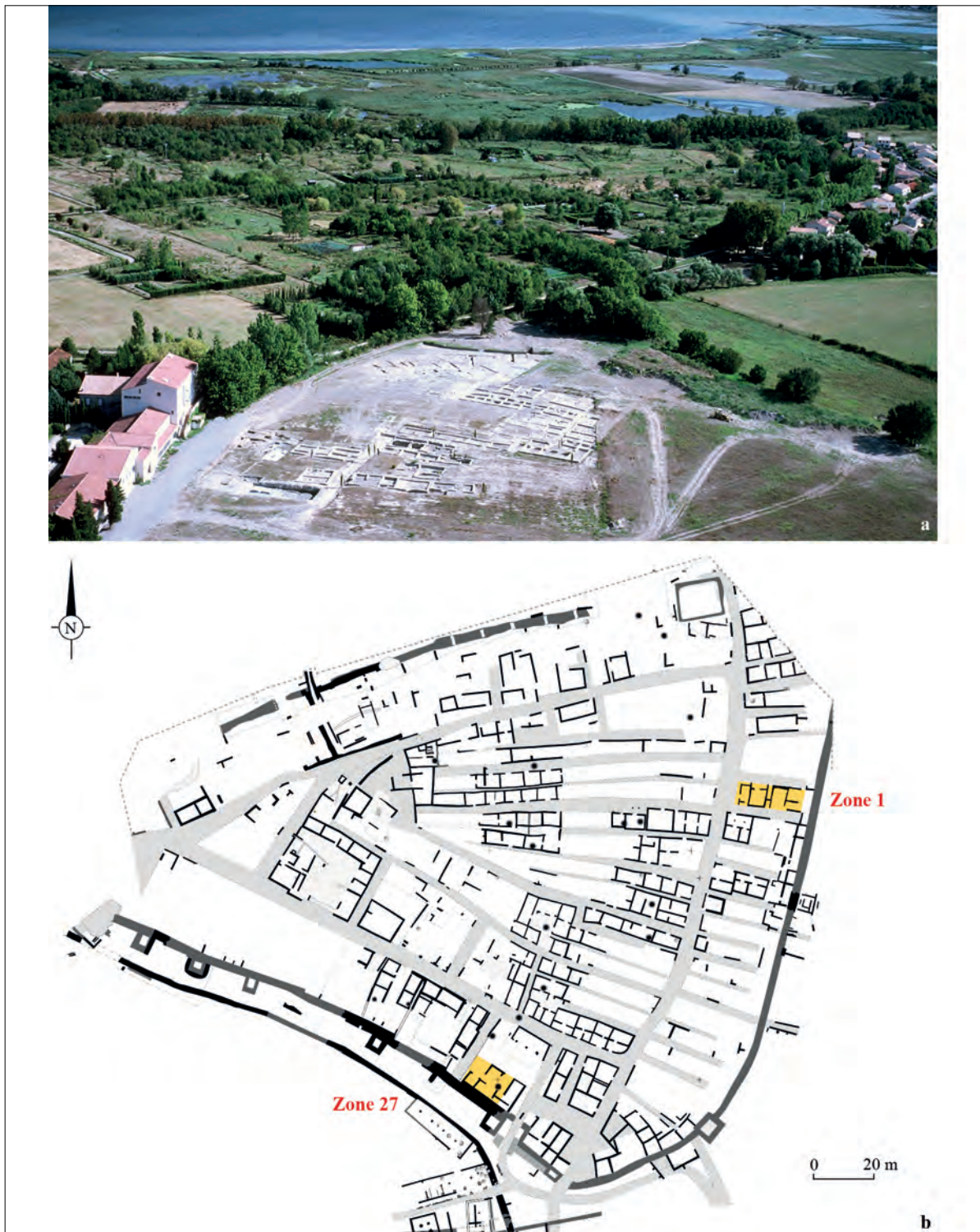


Fig. 6. The site of St-Sauveur at Lattes, ancient *Lattara*. a) Aerial view (© L. Damelet, CNRS/CC) and b) excavation map indicating the two deep excavations (Zones 1 and 27) which brought to light the earliest Etruscan levels.

The floor plans and construction techniques of the buildings of this early phase are clearly of Mediterranean style - with direct parallels to Etruria. This connection is confirmed by pottery revealing the key role of Etruscan materials, notably numerous amphorae among the Mediterranean imports. Indeed, while the assemblage of amphorae is dominated overwhelmingly by Tyrrhenian products during the first

quarter of the 5th century BC, the number of Etrurian table and kitchenware imports occupies a dominant position among the local or Greek-type products (**Fig. 7**). The originality of this facies is accentuated by many Etruscan graffiti corresponding mostly to marks of ownership carved directly on the surface of *bucchero nero* or other common Etruscan ware.

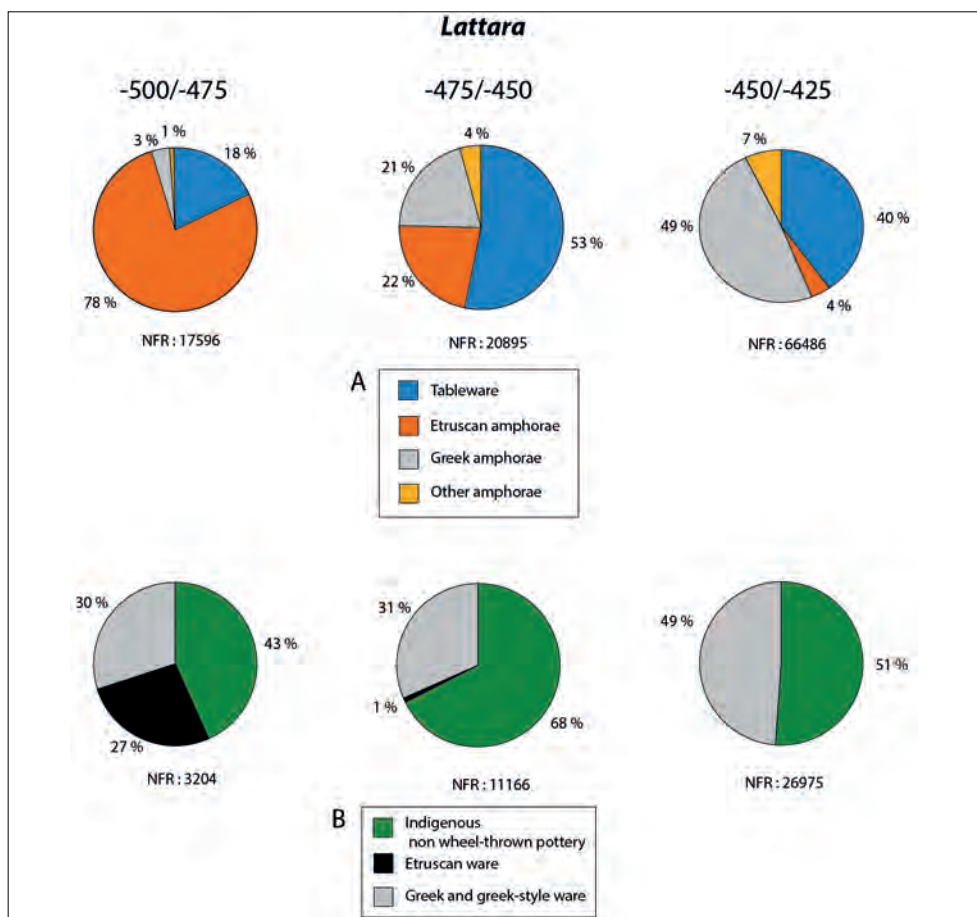


Fig. 7. Lattara. Evolution of the pottery facies between 500 and 425 BC.

A. Percentages of fine ware and coarse ware/amphorae;

B. Percentages of indigenous/Etruscan/Greek ware (NFR = “number of fragments”).

This early sequence of occupation comprising a community originating in Etruria dedicated to trade with the native Gallic populations was thus short-lived. It leads to speculate as to the exact nature of this colonial enclave founded along the border of the indigenous territory and linked, in one way or another, to the neighbouring settlement of La Cougourlude.

Its total destruction in about 475 BC and its rapid reoccupation by the native population was thus the prelude to a series of profound changes. The fact that at this time La Cougourlude was abandoned suggests that not only its inhabitants, but also its function as an “emporion” or “port of trade”, was transferred to nearby *Lattara* (Gailledrat 2015).

Besides a change in the architecture and urbanism introduced prior to the early 5th century BC, the new local phase saw a rapid evolution of its material culture. Although Tyrrhenian products (especially amphorae) persisted throughout the 475-450 BC interval, Etruscan daily ware, as well as the graffiti cited above, diminished and virtually disappeared. This clearly bolsters that the original inhabitants of *Lattara* disappeared by the first quarter of the 5th century BC. The finer pottery also was abandoned in favour

of a combination of local, hand-mounted models and a rapidly growing number of imports from Greek Marseille. The rate of Massalian amphorae increased to the point of becoming exclusive by the middle of the 5th century BC. This coincided with the increase of wheel-thrown Massalian cream-coloured ware and vessels of Massalian tradition reflecting a change in local consumption practices. It is even possible to speculate as to a constant presence of Greek merchants (possibly even craftsmen) among the native population in certain districts of the city.

THE GRINDING STONE ASSEMBLAGES

As in the case of the pottery, the grinding tools have likewise yielded data shedding light on the evolution of the dietary practices of both the native and Etruscan populations of about 500 BC. The total corpus of the macrolithic tools (862) from the two sites comprises at total of 333 grinding tools (as noted above, the rotary querns of *Lattara*, although at times cited here, do not form part of the current analysis) (**Fig. 8**).

	Quern lower stones ¹	Quern upper stones ¹	Hopper mills ¹	Undetermined grinding stones ¹	Quern making debris ²	Quern making flakes ²	Quern thermal flakes ²
La Cougourlude	34	42		40	26		
Lattara	92	45	13	67	82	414	13

Fig. 8. Quantification of quern elements at La Cougourlude and Lattara.
1. Minimum number of individuals (NMI); **2.** Number of elements.

	Quern lower stones ¹	Quern upper stones ¹	Hopper mills ¹	Undetermined grinding stones ¹	Stone debris ²	Quern flakes ²	Quern thermal flake ²
700 / 625 BC		2		1			
625 / 475 BC		1					
600 / 550 BC	1						
575 / 550 BC		1					
550 / 525 BC				1			
525 / 500 BC	1	5		5	10		
525 / 475 BC	3	3					
500 / 475 BC	11	16		16	12		
475 / 450 BC	1						

Fig. 9. Quantification of quern elements by chronological phase at La Cougourlude.
1. Minimum number of individuals (NMI); **2.** Number of elements.

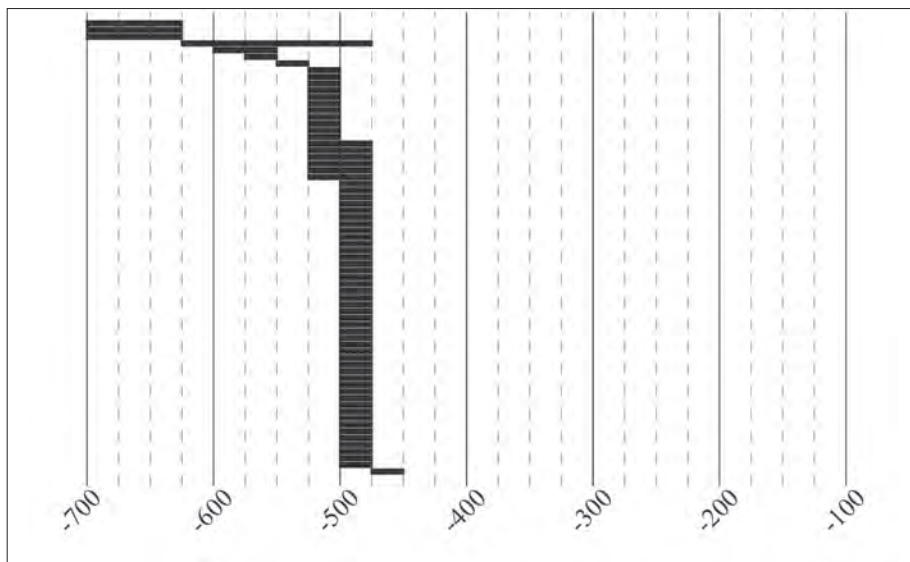


Fig. 10. Number of milling tools per chronological phase at La Cougourlude.

The assemblage from La Cougourlude (142), in turn, can be broken down into 116 fragments of quern upper and lower stones, and is the subject of a detailed study in the framework of the rescue operation. The assemblage thus offer compelling notions concerning milling ranging from the beginning of the 7th century BC, prior to the foundation of *Lattara*, and in particular for the turn of the 6th-5th centuries BC (**Fig. 9-10**). The assemblage of *Lattara*, in turn, benefits from a long tradition of study initiated by the seminal publication of M. Py (1992). His initial analysis focused on 104 hand quern and rotary querns ranging from 400 BC to 100 AD. Noteworthy

are also his systematic and scaled drawings. A second study of the assemblage was carried out by S. Raux (1999) comprising illustrations of about 40 stones. In any case, each of the two studies benefited from petrographic analyses (Dautria & Reille 1992; Reille 1999). The recent launch of the Collective Research Program of the Lez Valley (coordinated by I. Daveau) has led to a review of 217 hand querns and hopper rubbers (Olynthus mills) as well 509 flakes (**Fig. 11-12**). from *Lattara*. The current study therefore benefits from a total corpus of 333 to and fro querns and hopper mills from the two sites of La Cougourlude and *Lattara* spanning a period of 600 years.

	Quern lower stones ¹	Quern upper stones ¹	Hopper mills ¹	Undetermined grinding stones ¹	Stone debris ²	Quern flakes ²	Quern thermal flake ²
500 / 475 BC	2	4		1	1		12
500 / 300 BC	1						
475 / 450 BC	3	2		2			1
450 BC	3	1	1		2		
450 / 425 BC	5	1	1	9	8		
450 / 400 BC				1			
425 / 400 BC	18	13		18	2		
400 BC	5	1		3			
400 / 375 BC	13	7		8	1	2	
375 BC	8	2		1	3		
375 / 350 BC	4			3	6		
375 / 325 BC		1		1			
350 BC		1			3		
350 / 325 BC	2	1		5	8	3	
350 / 300 BC	1			1			
350 / 250 BC	1					4	
325 / 300 BC	2	3		1	15	23	
325 / 275 BC			1				
325 / 225 BC					1		
300 BC				1	4	4	
300 / 275 BC	1					12	
300 / 275 BC	3	2			2	7	
300 / 175 BC	1						
300 / 150 BC					1		
275 BC	1					81	
275 / 250 BC						11	
250 / 225 BC						3	
250 / 200 BC		1		1			
225 / 200 BC	3	3			1	10	
225 / 175 BC				1			
225 / 125 BC				1			
200 / 175 BC				1	1	1	
200 / 150 BC	1						
200 / 100 BC			1		1		
175 / 150 BC				1		1	
150 / 100 BC	1						
125 / 100 BC				1			

Fig. 11. Quantification of quern elements by chronological phase at Lattara (between 500 and 100 BC).

RAW MATERIALS

Most of the grinding stones from each of the sites were hewn of either effusive magmatic basalts (261; 78.38%) or sedimentary detrital quartz-rich sandstones or conglomerates (66; 19.82%). Other marginal materials at La Cougoulude include a single undetermined rock, two limestones (0.06%) and four granites (1.2%). Basalts and sandstones, accounting for the majority (98.2%), can be further subdivided into different facies based on visual observations. The latest petrographic data were confronted with Jean-Louis Reille's initial findings and with the results of geochemical analyses carried out on samples collected in the field from different regional outcrops (Fig. 13).

Basalts

Massive basalts

The grinding stones hewn of massive basalt vary in colour from light to dark grey, contain very few vesicles (Fig. 14) and millimetric to centimetric crystals. These rocks are analogous to materials observed in the Hérault Valley and in the basaltic flows of Caux and Nizas 50 kilometres to the west. J.-L. Reille reported that basanites from the Volcano of Célessou are the source of two stones at Lattes (Reille 1999). The survey carried out in the Hérault Valley in the hills of "Plan du Célessou",

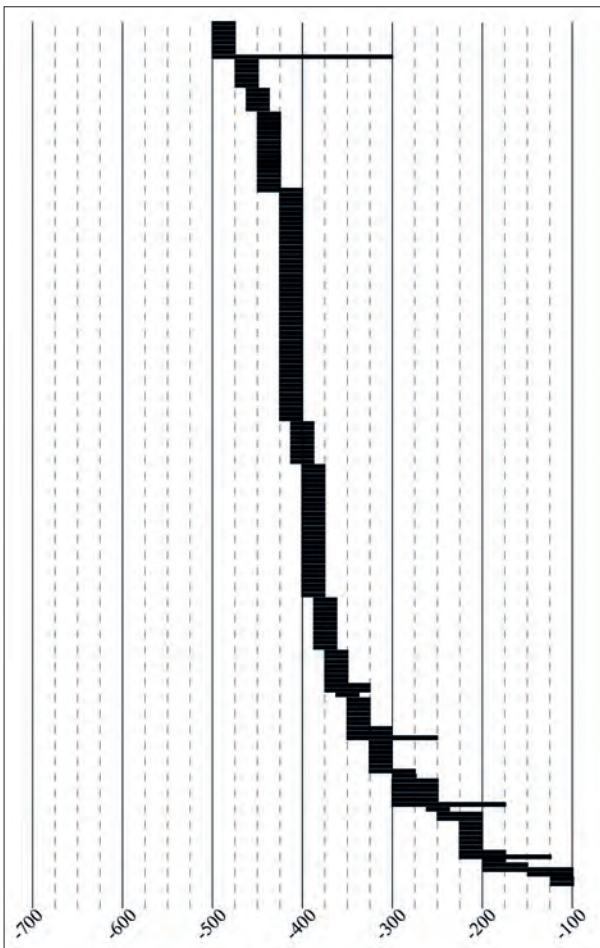


Fig. 12. Number of grinding tools per chronological phase at Lattara.



Fig. 13. Sources of the rocks and geological samples (S. Cousseran-Néré).



Fig. 14. Macroscopic view of a massive basalt (La Courgoulude, Fs 10501, US 10501-I. Daveau, Inrap).

“Moulin d’Anquet” and “Roque Maurel” in Fontès, and in the Municipalities of Caux and Nizas, yielded a similar material from the macroscopic standpoint. Yet, this brief field work did not identify any blanks, roughouts or characteristic working debris that confirm their quarrying. It is also noteworthy that Dautria and Reille, in their 1992 description of the basalts from Lattes, reported a massive basalt outcrop with columnar jointing at Montferrier a few kilometres north of Lattes (Dautria & Reille 1992, 236). Yet despite of its massive character, the authors noted that it did not fall in line with the granular structure of the *Lattara* stones.

Vesicular basalts

Contrary to the previous rock, this light grey basalt is highly vesicular, marked by cavities measuring between 2 mm to more than 1 cm (Fig. 15). The rock is analogous to samples from the outcrops of Cap d’Agde (Dautria & Reille 1992, 236) and Saint-



Fig. 15. Macroscopic view of a vesicular basalt (La Courgoulude, Fs 30230, US 30793-I. Daveau, Inrap).

Thibéry (Reille 1999), each about 50 km to the south-west. The first petrographical study concluded that almost all the grinding stones dating between the 3rd and 1st centuries BC were hewn of vesicular basalt from Cap d’Agde (Dautria & Reille 1992). A second study of the 4th century BC assemblage noted that many of the vesicular basalts came from Saint-Thibéry-Bessan (about 15 km north of Agde) and that the basalts of Agde played a secondary role in their manufacture (Reille 1999). Certain vesicular basalts are likewise from Toulon, more than 200 km away. Among the stones sourced by Raux (1999) that form part of the current study are basalts from Saint-Thibéry characterised at times by small stretched vesicles and small white crystals.

Basalts with black crystals

This volcanic rock, also grey, contains numerous vesicles measuring less than a centimetre and black crystals, potentially amphiboles.

Basalts with leucite crystals

The last basalt of this study is a grey vesicular magmatic rock containing white leucite, pyroxene and olivine crystals. The presence of feldspathic leucite in lieu of feldspar renders this rock simple to characterise by the naked eye. It is exogenous, imported from the Italian Peninsula in Etruria (Lazio District), mainly from outcrops in the surroundings of the town of Orvieto. These outcrops are known to have been intensely exploited for millstones throughout Antiquity, notably for Pompeian millstones (Peacock 1986). The petrographic analyses carried out on the materials at *Lattara* confirm the presence, although in small quantities, of hand querns from Orvieto as early as the 4th century BC (Reille 1999: 521).

Provenance of the volcanic stones

A total of 11 samples were taken from the grinding stones of Cougoulude (8) and *Lattara* (3) for geochemical analyses (Fig. 16). The major element and trace element compositions were analysed by wavelength dispersive X-ray fluorescence at the Institute of Geosciences, University of Mainz, Germany. Dried powder melted into molten glass beads served to determine the major elements. Powder pellets, in turn, served for trace element determinations. In order to identify provenance, their geochemical compositions were contrasted with geological data gleaned from publications as well as geological samples collected at the potential quarry sites by S. Cousseran-Néré (Languedoc), L. Jaccottey (Languedoc and the Massif Central) and T. Gluhak (Massif Central).

	La Cougourlude	Lattara
Massive basalt	Fs 10497 Fs 30230	Us 53756-1
Vesicular basalt	Fs 20236 Si 40003 Fs 10379 Fs 30230 Us 30779 Fs 30433	
Basalt with black crystals	Us 40000	
Leucite basalt		Us 69347-6 Us 69393-1

Fig. 16. List of the samples subject to petrographical analysis.

The fine-grained volcanic rocks were classified in a TAS diagram (Fig. 17) and the rock types listed in Table 1. Two high-alkali samples are tephri-phonolites (SU 69347-6 and SU 69393-1). All of the other samples reveal lower alkali and silica content. Five are alkali basalts (Fs 30230, Fs 10497, Si 40003, Fs 20236, Fs 30230 Us 30779). Three, in turn, correspond to trachybasalts. On the basis of their potassium oxide (K₂O) and sodium oxide (Na₂O) content, they can be further broken down into hawaiteites (Fs 30433, Us 53756-1) and potassium trachybasalts (Us 40000). A single sample (Fs 10379) trends the line between basalts and trachybasalts (hawaite).

The results indicate two completely different types of rock served for grinding stone manufacture. The published data confirms that the two leucite tephri-phonolite examples are imports from Orvieto, Italy (Fig. 18a). The ratio between barium (Ba) versus strontium (Sr) is particularly useful in distinguishing the singular properties of Orvieto lava. Moreover, it is possible to conclude that the stones were specifically hewn from the Sabatini region of the Orvieto volcanic district (Fig. 18b).

All the other samples most likely point to the exploitation of French volcanic outcrops. The comparison of the finds with

published geochemical values and volcanic samples collected in the field suggest that samples SU 40000, Fs 30433 and Fs 10379 correspond most likely to outcrops from Auvergne, whereas the others point to a wider extension englobing volcanic outcrops not only from Auvergne but elsewhere in southern France (TAS diagram; Fig. 19a).

The presence of magnesium oxide-phosphorus pentoxide (MgO-P₂O₅) and magnesium oxide-Niobium (MgO-Nb) (Fig. 19a-b) suggests that the stones of US 40000, Fs 30433, Fs 10379 and Fs 30230US 30779 were procured from Auvergne outcrops. Although no specific origin can be determined from the data currently available, these samples reveal a geochemical affinity with rocks from Mont Dore. The four querns of Auvergne probably come from three different outcrops. The geochemical composition of the hawaite cases (Fs 30433 and 10379) bear many similarities and therefore presumably share the same source. The slight differences in the content of aluminium oxide (Al₂O₃), sodium oxide (Na₂O) and phosphorus pentoxide (P₂O₅), for example, are well within the range of natural heterogeneity within the same lava.

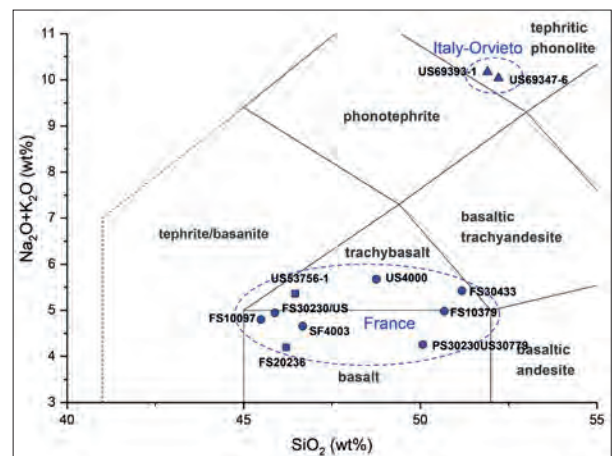


Fig. 17. Classification of the samples in a total-alkaline silica (TAS) diagram (Le Bas et al. 1986).

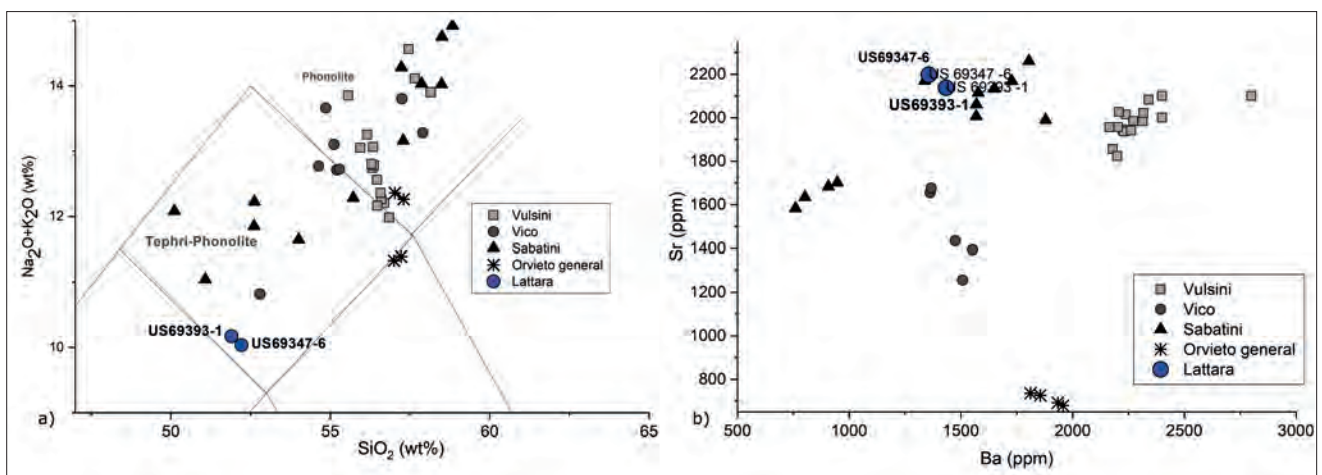


Fig. 18. Diagrams comparing the leucite querns of Lattara with data from Orvieto, Vulsini, Vico and Sabatini (Antonelli et al. 2013) and Orvieto in general (Buffone et al. 2003).

of La Cougourlude also comes from Auvergne (although few samples from Lattes were studied). Exogenous volcanic long-distance imports from Orvieto (Italy), in turn, are only present at *Lattara*.

Coarse sandstones and limestones

Although the assemblage consists of a variety of sandstones and conglomerates, two-thirds were hewn from coarse heterogeneous layered conglomerates containing milky, hyaline angular quartz grains. The dimensions of the grains vary between 0.1 and 0.5 cm with some coarser sequences of quartz grains exceeding 2 cm (**Fig. 20**). The grain size serves to define these materials as conglomerates. They also contain rare fragments of black siliceous jasper or radiolarite and a few centimetric white feldspars. All of these elements are contained in an ocher siliceous matrix at times marked by reddish layers. This facies was identified during geological surveys (S. Cousseran-Néré and F. Convertini) in the Upper Hérault Valley in the Gabian Municipality (SW of Lake Salagou) and at Lamalou-les-Bains (W of Lake Salagou) at outcrops along the Triassic base (t2). Similar facies are to the north of Lake Salagou, at Lodeve, and to the west at Mérifons at more recent Triassic level outcrops (t6-7). A small series of stones of a finer facies than the quartz-rich examples was identified to the north-east of Lake Salagou near the Municipality of Saint-Jean-de-la-Blaquière and to the south of the Lake Salagou near the Liausson and Gabian Municipalities among the intermediate Triassic (t 5-6) levels. In any case, all of these formations are in the Upper Hérault Valley around Lake Salagou, 60 km northwest of Lattes. Furthermore, the fragments of limestone querns containing quartz grains and bivalve shell fragments can be sourced to the Oligocene formations in the Pignan region, 15 km to the west of the two sites.

THE GRINDING TOOLS OF LA COUGOURLUDE AND LATTARA

La Cougourlude

The grinding stones of La Cougourlude, despite recurring features, reveal great diversity (**Fig. 21**). A first characteristic is the careful shaping of their edges, ends and back, reflected in most cases by a more or less partial pecking of the non-grinding surfaces. The grinding surfaces themselves are flat or concave longitudinally and flat or slightly convex transversely. Use-wear traces, although spread over their entire surfaces,



Fig. 20. Macroscopic view of a coarse sandstone (La Cougourlude, PO40374, US 40374, I. Daveau, Inrap).

are more intense along the edges and ends. These types of grinding surfaces and their distribution of use-wear serve as evidence of their coupling with overlapping upper stones, that is, models that are longer than the width of the lower stones. They comprise five types: short sub-circular, short quadrangular, oval, flattened-oval and naviforme. Yet, a crossing of the typological and petrographic data indicates one or more possible shapes for each rock type. Massive basalt, the most common, takes on the form of oval types with semi-oval sections, oval types with flattened ends and trapezoidal sections, and short quadrangular types.

Coarse sandstone served for oval and a single short quadrangular upper stone. The single vesicular basalt case is sub-circular, and the only grey coarse sandstone is naviforme. It therefore appears that there were specific productions according to the type of rock which suggests the existence of workshops yielding standardised models.

All the upper stones are oval with a more or less high semi-oval transversal section (**Fig. 22**). Their grinding surfaces are slightly concave in the longitudinal sense, with the exception of a few coarse sandstones that are flat, and a vesicular basalt that is slightly convex. These cases, apart from a half dozen flat examples, have a slightly convex transversal grinding surface. Three measures between 29 and 33 cm, a length that surpasses the width of all their lower stones suggesting they also to be overlapping.

As in the case of the lower stones, it is also possible to distinguish typological characteristics specific to a rock type. Yet there can exist within the same lithology very homogeneous assemblages.

Thus, massive basalt upper stones are oval with rounded ends, while those of coarse sandstone bear lateral hand grips.

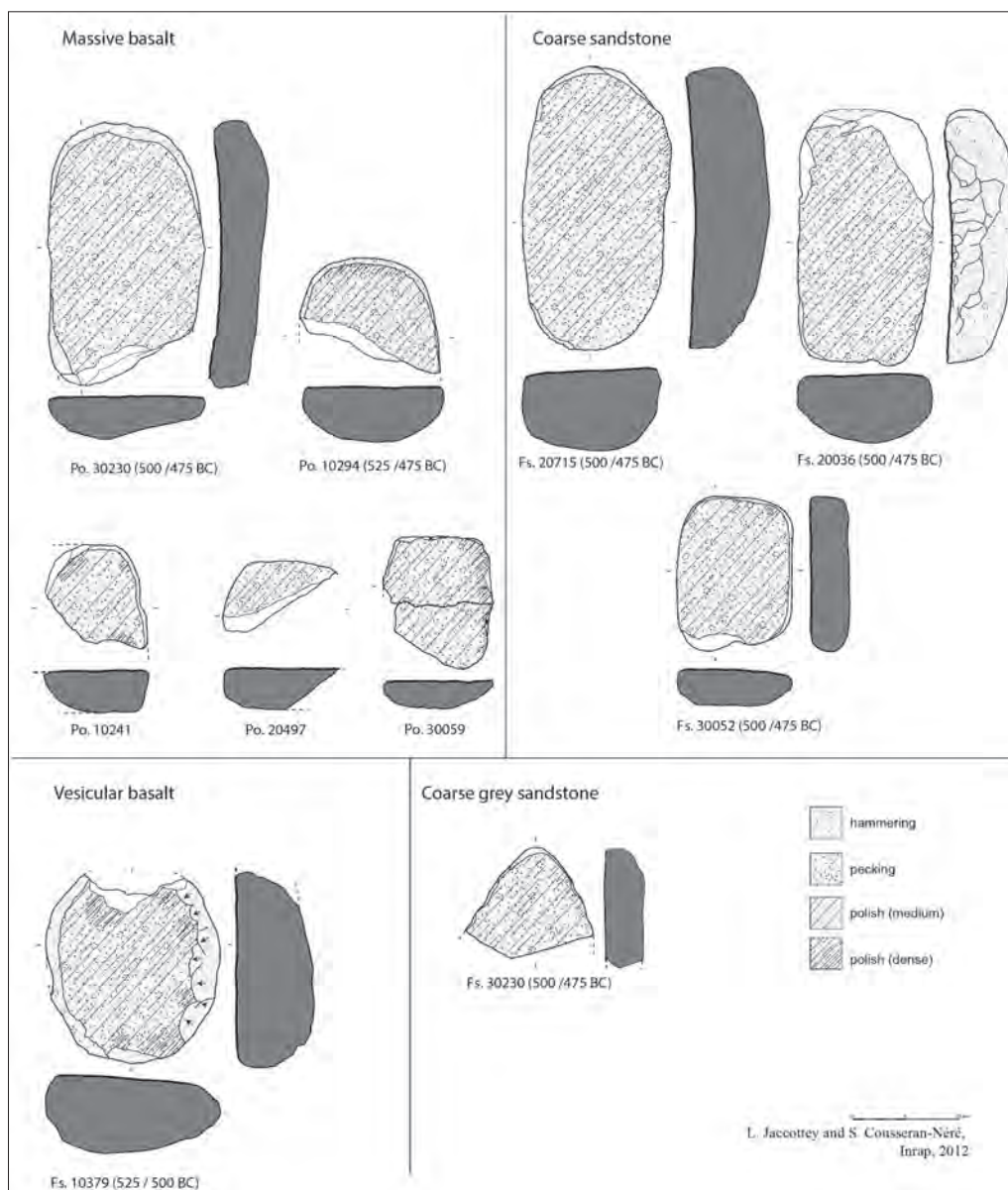


Fig. 21. Querns (lower stones) from La Cougourlude.

The single upper stone of vesicular basalt, in turn, has a flattened end. These observations bolster the notion of standardised productions made by specialised craftsmen and workshops.

Lattara

The assemblage of *Lattara*, contrary to that of La Cougourlude, comprises three types of mills: hand querns, hopper rubbers and rotary querns (Fig. 23). The traditional hand querns driven with a to-and-fro motion are present from the outset of *Lattara's* occupation and abundant until the early 4th century BC. They include a number of rectangular slabs, labelled “tables”, that could have been coupled with either the upper stones of querns or hopper rubbers. These are also present from the earliest phase of the occupation until the

outset of the 4th century BC. Hopper rubbers, evidenced since the middle of the 5th century BC, are never predominant.

The first rotary quern identified at Lattes is from a late 5th century BC level. This more sophisticated mill type developed during the 4th century BC in parallel with a decline of hand querns and hopper rubbers. From the end of the 4th century, the older to and fro querns were supplanted by rotary models. The older models unearthed in these archaeological levels are therefore residual. Moreover, the chronological range of this study for *Lattara* can be extended from the outset of the 5th century to the end of the 4th century BC.

The *Lattara* assemblage comprises coarse sandstone and massive basalt upper and lower quern stones similar to those of La Cougourlude (Fig. 24). Vesicular basalts are

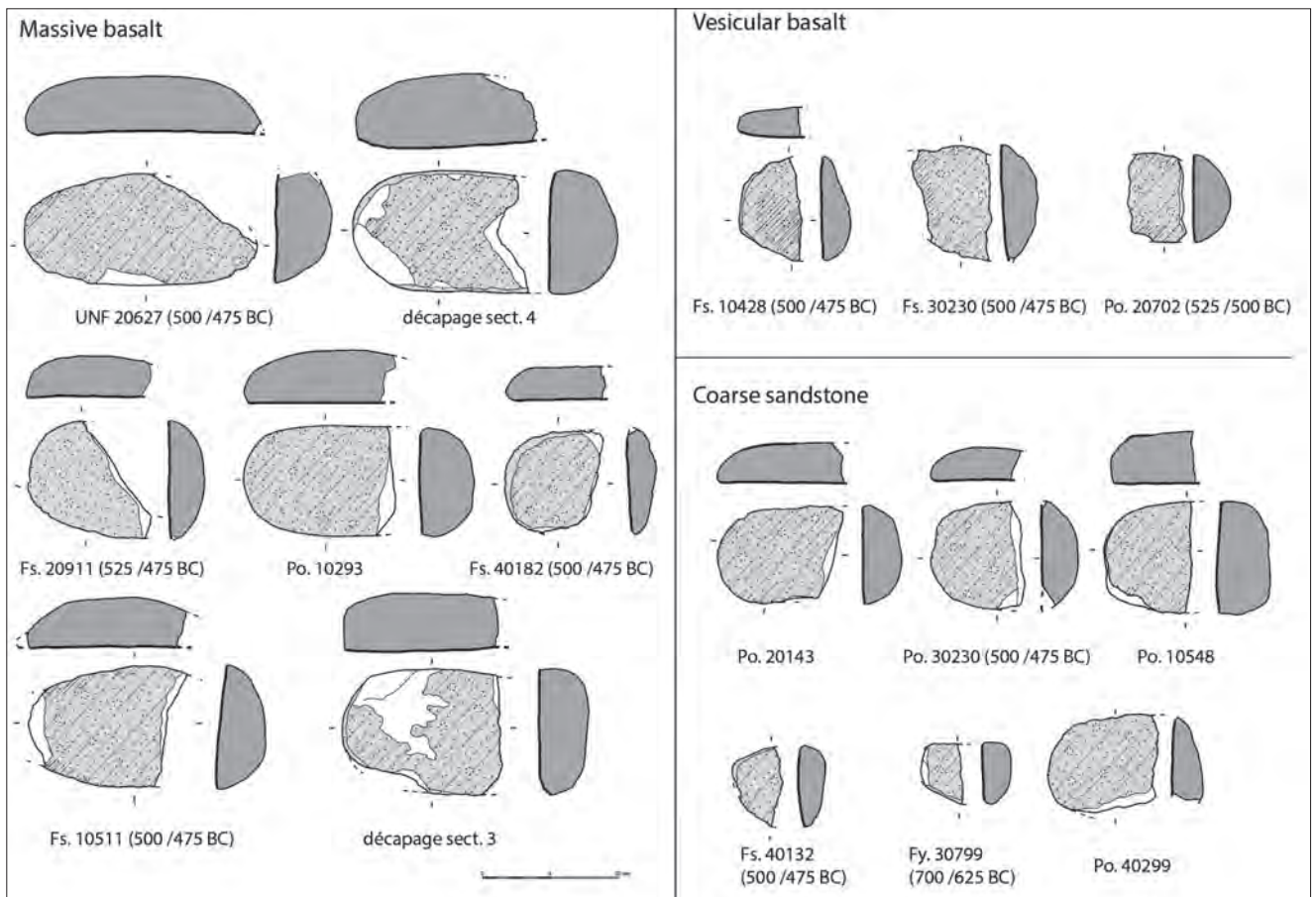


Fig. 22. Upper stones from La Cougourlude.

nonetheless more common. The five include a whole example which is larger than its sandstone and massive basalt oval counterpart (55 cm in length, 34 cm in width). One of its rounded ends is much narrower than the other resulting in a teardrop shape. Oval upper stones of vesicular basalt are also longer and narrower than their sandstone and massive basalt counterparts.

There are also examples of quadrangular, sharp-angled vesicular basalt tables bearing leucite crystals (Fig. 25). Their longitudinal or transverse sections are quadrangular or oval and their grinding surfaces mostly flat. Their backs are also flat and roughly pecked. One of the backs of a leucite model reveals traces of fashioning with a pointed metal tool (chisel or pick).

A few upper stones with triangular sections, straight backs and sub-vertical ends were carved from these rocks (vesicular basalt or basalts with leucite crystals). A whole upper stone 46 cm long, 13 cm wide and 7.3 cm thick (Fig. 25) has a slightly

concave longitudinal and transversal grinding surface. The presence of a small step stretching across towards each end of the grinding surface evidences the greater wear on the stone's entire central area, a characteristic of overlapping upper stones. Its fashioning is very thorough as seen by finely pecked back and flanks. A triangular notch was cut a few cm from each end of the back to lodge the thumb facilitating the grip.

The hopper rubber (Olynthus mill), a different type of mill of Greek tradition, was introduced in the middle of the 5th century. Its lower stone is table-shaped (see above). The eight cases (one whole 40 x 32 cm and seven in fragments) are quadrangular, finely pecked and hewn from vesicular basalt (Fig. 26). Halfway up the edges of their ends they bear a horizontal flute intended to lodge a wooden frame that served for their means of traction. All the upper stones bear a rim 3 to 5 cm wide circumscribing a central slit serving as a hopper to feed the grains. These mills are homogeneous from typological and petrographical standpoints and evidence a standardised production in specialised workshops.

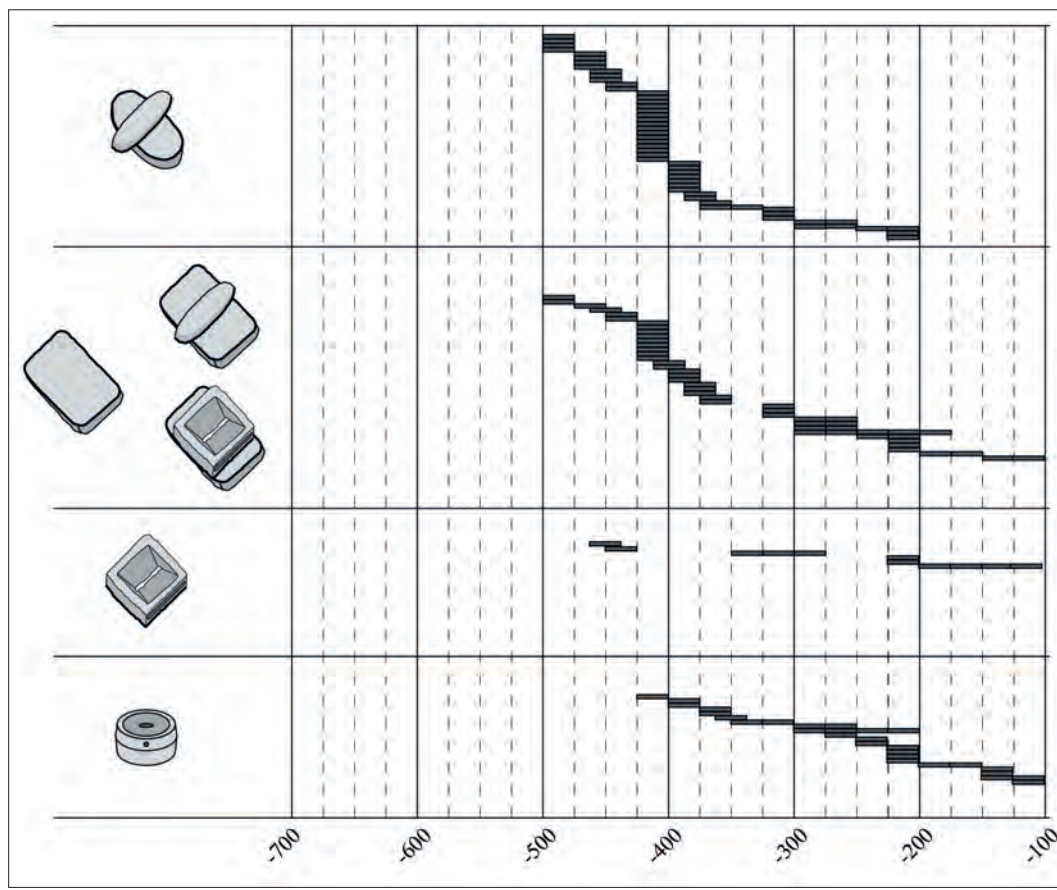


Fig. 23. Evolution of grinding tool types at Lattara.

CONCLUSIONS

All the to and fro querns and hopper rubbers from the sites of La Cougourlude and *Lattara* benefitting from chronological and petrographic analyses were gathered into a chart (Fig. 27). The first notion garnered from the diagram is that the basalt models span the entire period of the study while sandstones (except for a few residuals) disappear after 300 BC.

Yet the main point gleaned is the opposition of models hewn from massive basalts at La Cougourlude and those of vesicular basalt at *Lattara*. Massive basalts, probably from the Middle Hérault Valley, represent 50 to 60% of the Cougourlude corpus while they only embody a small proportion of the *Lattara* corpus until around 350 BC. Conversely, the number of vesicular basalts at La Cougourlude, whose origin can be traced respectively to the Lower Hérault Valley (Bessan & Saint-Thibéry) and Auvergne, is modest (12 to 22%) while they are considerable at *Lattara*, especially after 450 BC when they surge from 40% to more than 80%.

Apart from the marked contrasts between massive and vesicular basalts, leucite basalts from Italy, absent at La Cougourlude, make their appearance (about 30% of the

corpus) among the earlier occupations of *Lattara* between 500 and 475 BC. The proportion of these imported rocks then decreases rapidly in the second half of the 5th century BC and throughout the 4th century (Reille 1999).

Coarse sandstone querns appear at La Cougourlude from the first half of the 6th century BC represented by between 15% and 30% of the corpus. Their presence at *Lattara*, on the other hand, persists in similar proportions until the end of the 4th century BC.

It is noteworthy that *Lattara's* first phase of occupation (between 500 and 475 BC) reveals equivalent proportions of Italian basalt, vesicular basalt and sandstone, materials that sharply contrast with those of La Cougourlude. The Italian leucite querns fall in line with the presence of a large Etruscan community at *Lattara* manifested by pottery imports from Etruria. *Lattara* in its next phase between 475 and 450 BC, by contrast, only reveals massive basalts and sandstones, a scenario analogous to that of La Cougourlude. *Lattara* was then suddenly destroyed by a fire towards 475 BC as evidenced, among others, by the many thermal flakes detached from the grinding stones (Fig. 13). The site was then very rapidly re-occupied by a mainly native population, a notion bolstered in part by the study of grinding tools. Then, from about 450 BC, the

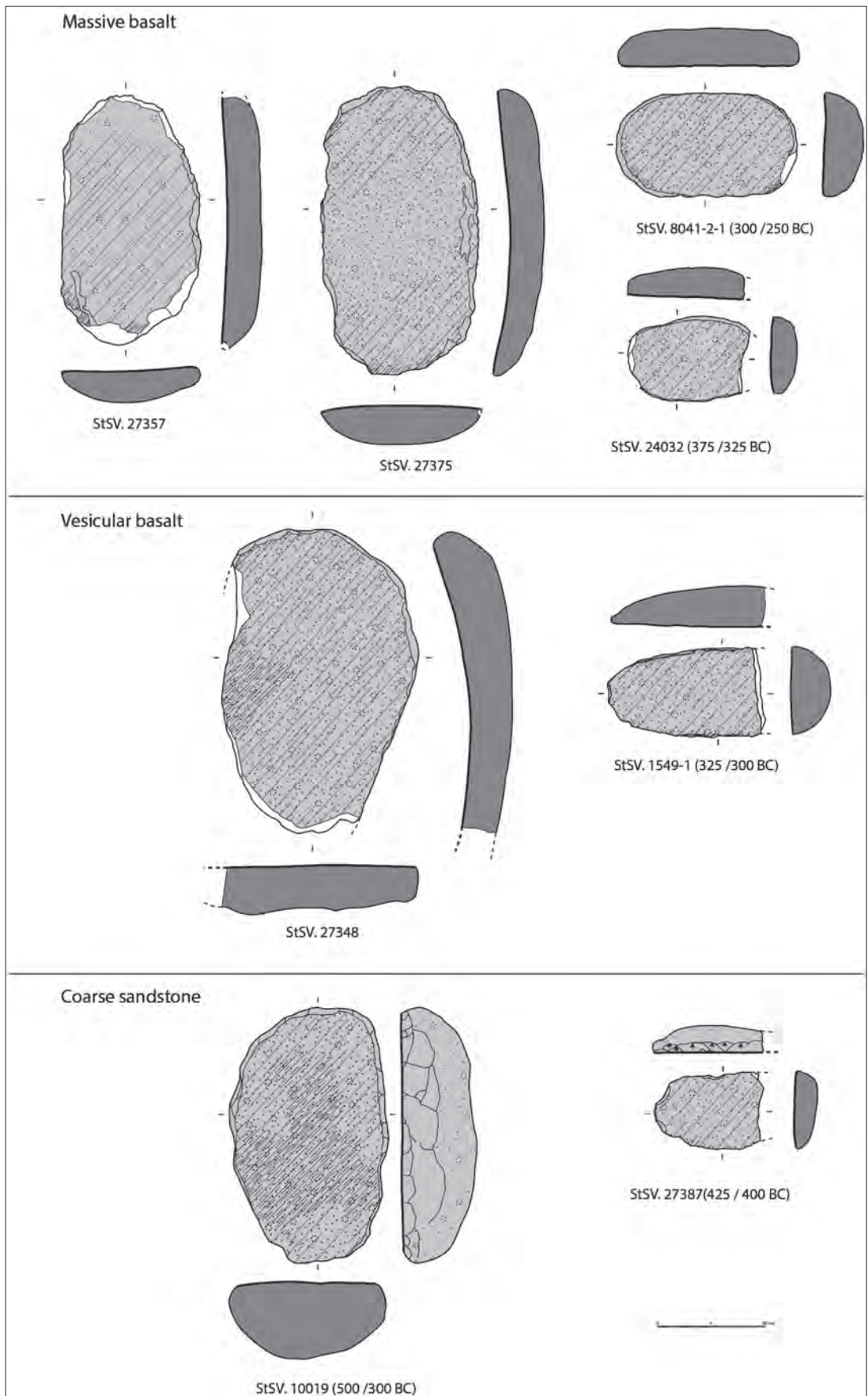


Fig. 24. Oval querns and upper stones from Lattara.

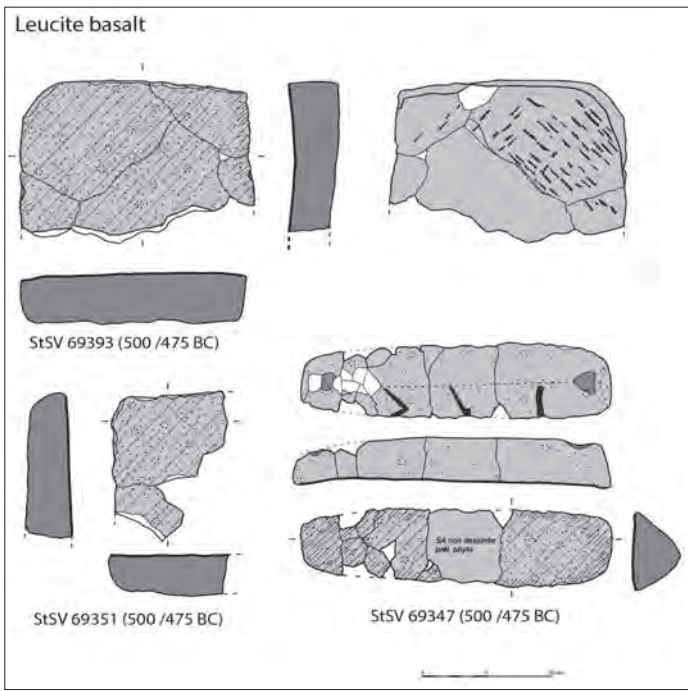


Fig. 25. Leucite basalt querns from Lattara (quadrangular tables and triangular sectioned quern).

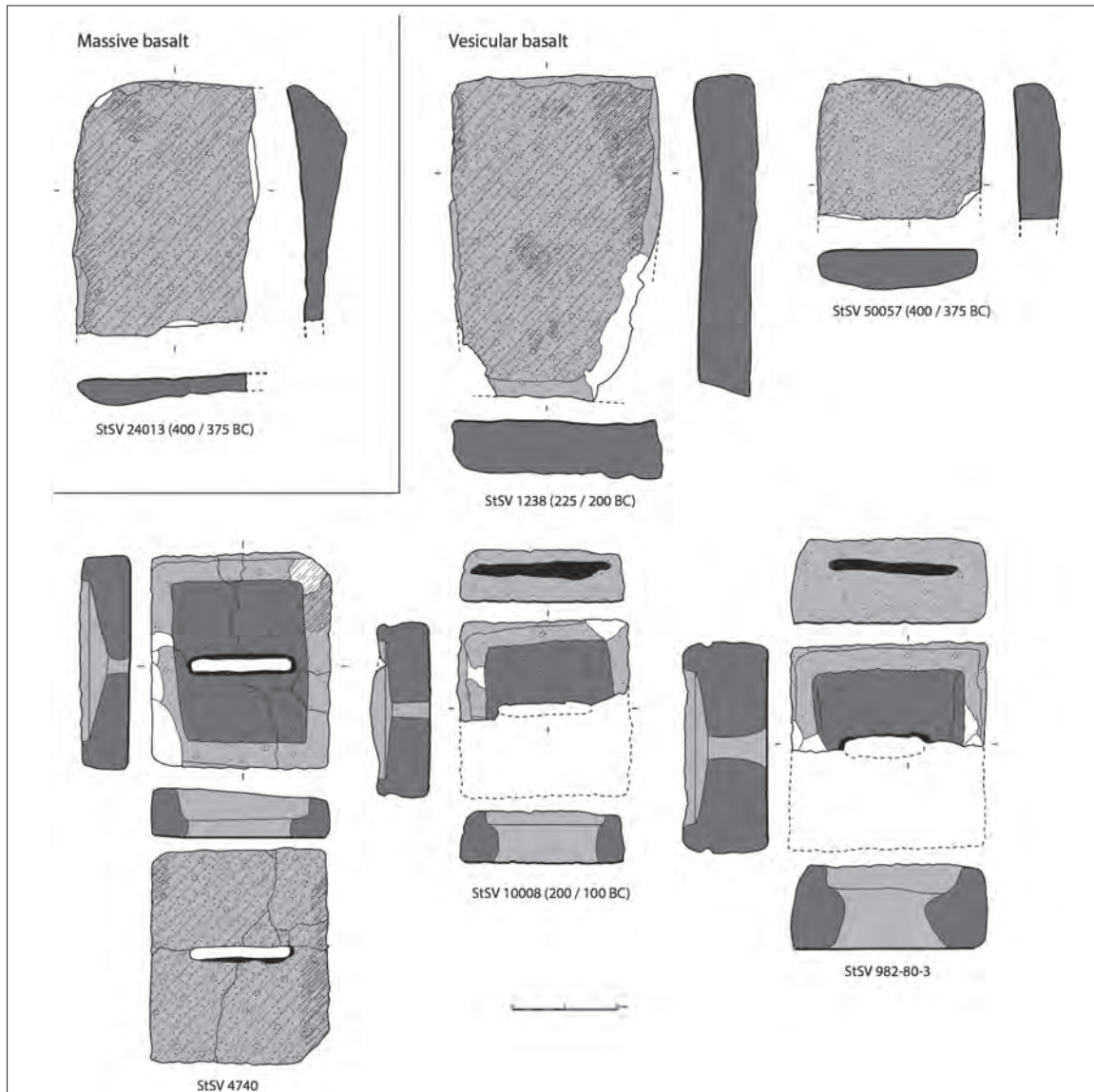


Fig. 26. Quadrangular tables and hopper rubber from Lattara.

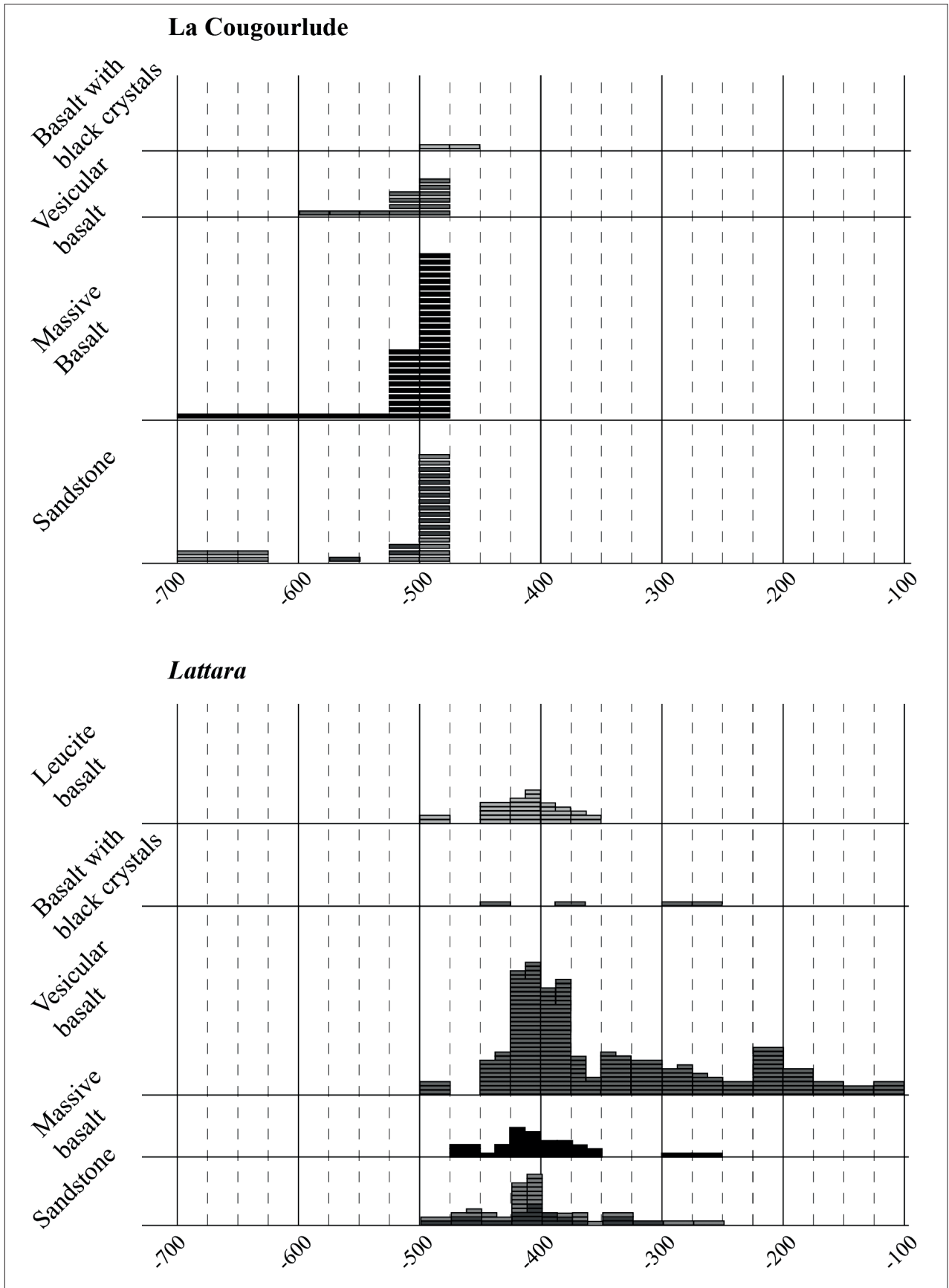


Fig. 27. Chronology of the raw materials serving to produce lower and upper quern stones at La Cougourlude and Lattara.

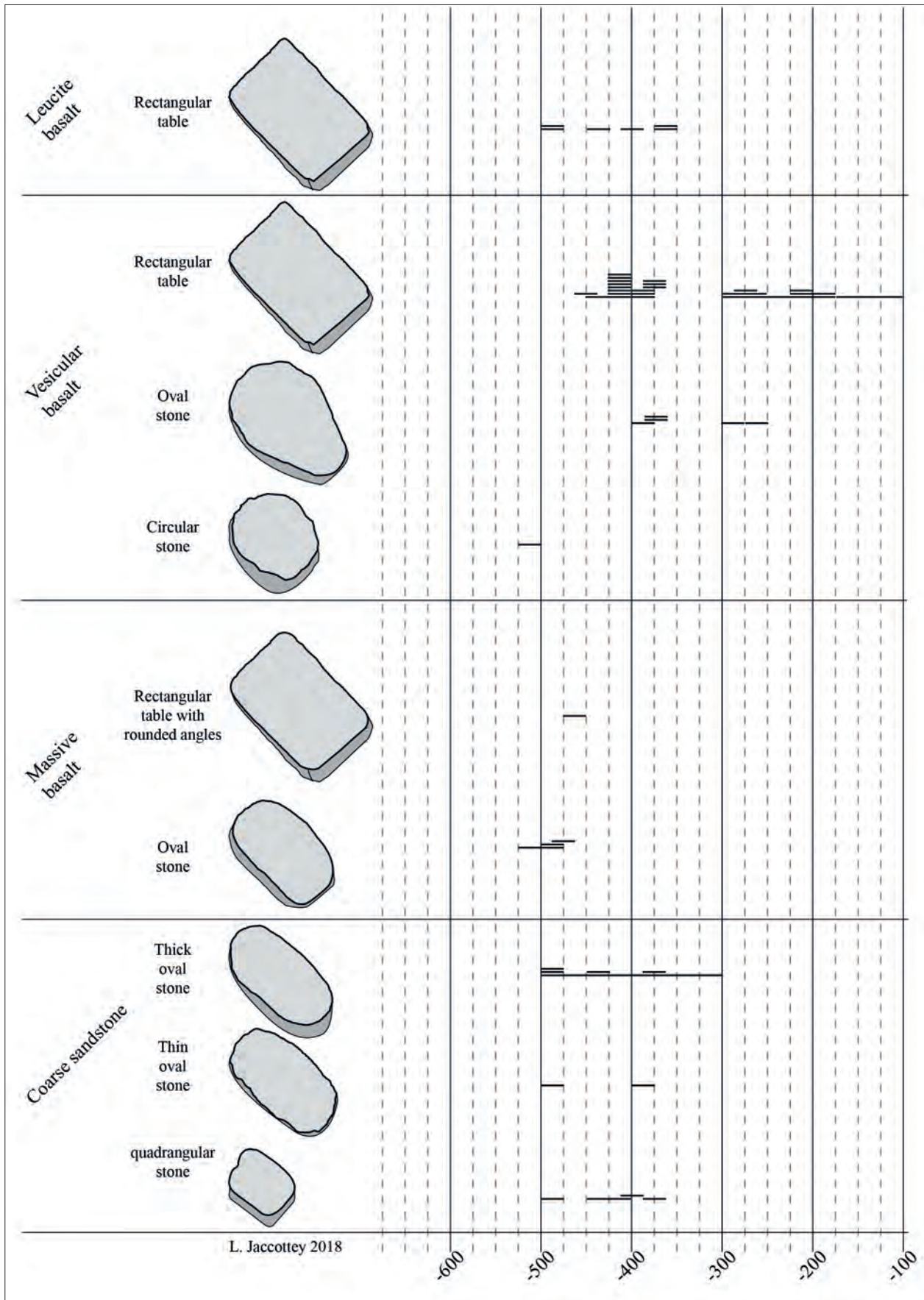


Fig. 28. Chronology of the types of lower stones according to rock type at La Cougourlude and Lattara.

proportion of local materials (sandstones and massive basalts) plunged rapidly, substituted for the most part by vesicular basalts procured largely from the regions of Bessan and Saint-Tibéry (Reille 1999) and subsequently Agde (Dautria & Reille 1992). This coincides with the Massalian colonisation of Agde initiated at the end of the 5th century. The increase of products arriving from the Lower Hérault Valley is likewise concomitant with an increase in the number of amphorae imported to *Lattara* from Marseille.

There is therefore a real contrast between the sites of *Lattara* and La Cougourlude in terms of grinding stone raw materials and procurement systems. Those adopted at the Gallic site of La Cougourlude were essentially regional materials brought from the Upper Hérault Valley. On the contrary, the site of *Lattara*, probably founded by Etruscans, was initially marked by the appearance of basalt grinding stones of Italian origin. These rocks, totally absent at the neighbouring native site, are clear evidence of the direct import of grinding stones by the first settlers of *Lattara*. The materials commonly serving to fashion the stones at La Cougourlude became progressively marginal and were replaced by volcanic rocks extracted farther down the Hérault Valley in the Municipalities of Bessan and Saint-Tibéry. These rocks, already present in small numbers at Cougourlude, then became predominant at *Lattara*.

As in the case of the petrography, placing the different types of grinding stones in their chrono-typological contexts also offers relevant data. Yet this aspect is less developed as the number studied to date is very limited. Thus, only a few querns and tables of each chronological period benefitted from analyses with the exception of a series from the outset of the 5th and 4th centuries BC (respectively 13 and 15). The circumstances are similar for the upper stones of both hand querns and hopper rubbers as they are only well-represented at the beginning of the 5th century BC. These initial results and hypotheses must therefore be validated in the coming years by new finds. Despite these limitations, we advance the following notions.

It is possible to discern an evolution between the upper stones and tables by placing all the circular and oval shaped

examples in one group and all the quadrangular cases in another (**Fig. 28**). The first fall into a chronological range between 525 and 250 BC while the second extend from 500 to 150 BC. The rounded stones represent twice the number of the angular models for the range from 500 to 475 BC mainly at La Cougourlude. These oval samples are essentially sandstones and massive basalts. By contrast, at *Lattara* between 400 and 375 BC, there are eight angular cases corresponding to tables hewn almost exclusively of vesicular basalt.

Oval upper stones are present from 525 BC and begin decreasing in number from 400 BC when they are first replaced by sandstones, then from 475 BC by massive basalts, and then from 375 BC by vesicular basalts (**Fig. 29**). Apart from the Italian leucite querns of triangular section dated from 500 to 475 BC, the only other case of this type is a vesicular basalt dated to around 350 BC. Finally, hopper rubbers appear from 450 BC and will endure until their replacement by rotary querns. These different upper stones therefore reveal new trends at *Lattara*, in particular a Greek influence characterised by the introduction of hopper rubbers.

The study of the grinding tools of La Cougourlude and *Lattara* offers key data as to the long term evolution of grinding stones ranging from the outset of the 7th century BC to the end of the 4th century BC. It is thus possible to trace the transition from the traditional hand querns linked to the native communities of La Cougourlude until the beginning of the 5th century BC marked by the arrival of Etruscan communities in *Lattara* whose inhabitants reverted to their own types of models imported from Italy. The destruction of the Etruscan phase at *Lattara* in 475 BC and its reconstruction by native Gallic populations, in the framework of close links to the Greek world, saw in the reintroduction of local querns whose number rapidly decreased in benefit of other models, including those of Greek influence, some of which came from quarries of the nearby colony of *Agathé* (Agde). Hence grinding tools prove to be a compelling tool serving to pinpoint population trends among the different centres along the Mediterranean coastline marked to strong Etruscan and Greek influences.

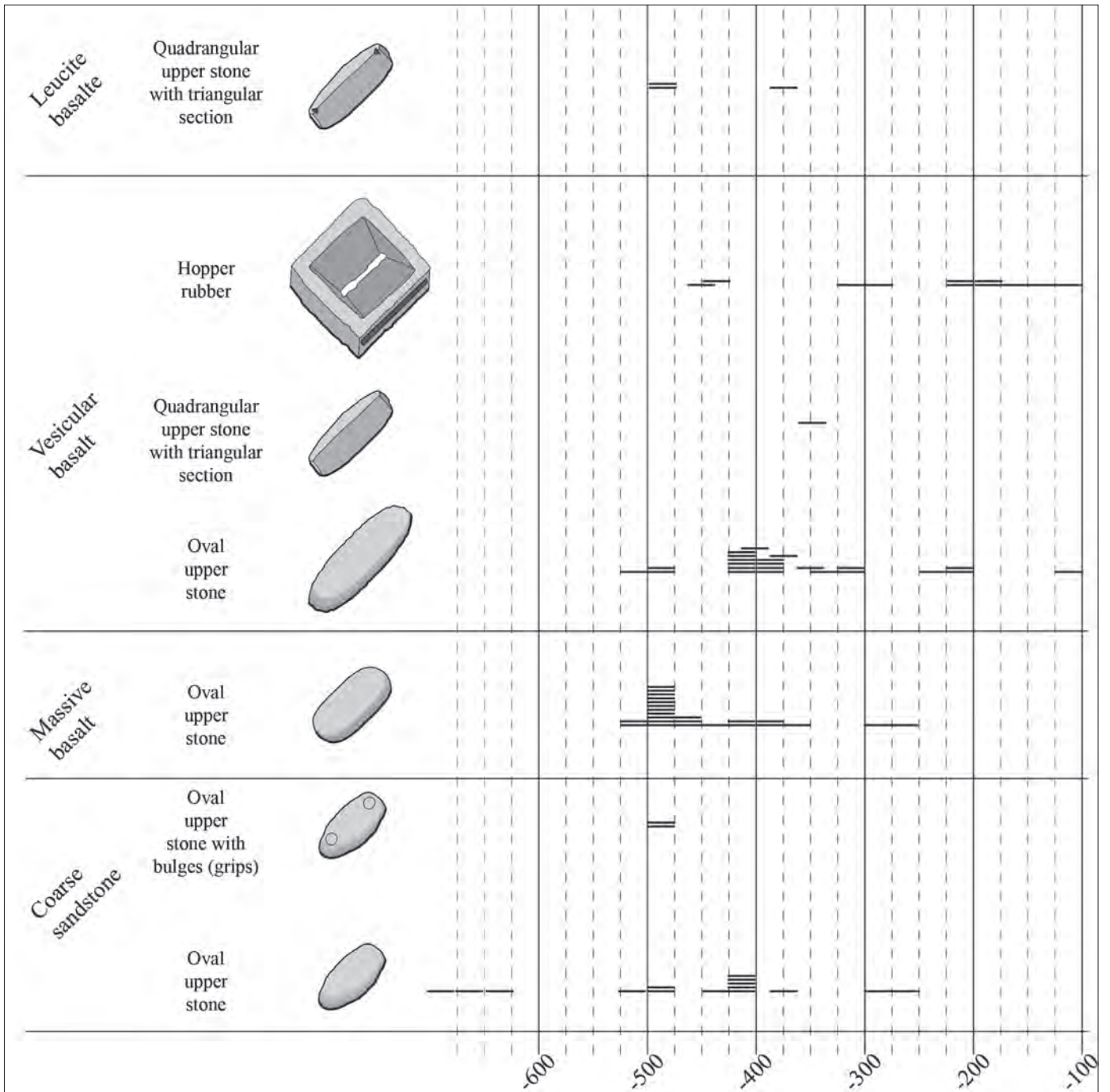


Fig. 29. Chronology of the types of upper stones according to type of raw material at La Cougourlude and Lattara.

BIBLIOGRAPHY

- Antonelli, F. and Lazzarini, L. (2010): "Mediterranean trade of the most widespread Roman volcanic millstones from Italy and petrochemical markers of their raw materials", *Journal of Archaeological Science*, 37, 2081-2092.
- Baubron, J.-C. and Demange, J. (1982): "First geochronological study of the volcanic plateau of Aubrac (French Massif Central) - tectonic and regional implications", *Journal of Volcanology and Geothermal Research*, 1-2, 67-75.
- Bergern, E.T. and Olives, J. (1976): "Contribution to the study of alkaline lavas of Velay Oriental (France): The Coriox des Boutiers Sector", *Comptes Rendus Académie des Sciences*, Paris, Serie 2A, 283.
- Boudon, G. and De Goer de Herve, A. (2001): "Leucite Nephelinites and Leucite Basanites North and East of Cantal (French Massif Central)", *Comptes Rendues de l'Académie des Sciences*, Paris, Ser. 2A, 286, 1645-1648.
- Briot, D., Cantagrel, J.-M., Dupuy, C. and Harmon, R.-S. (1991): "Geochemical evolution in crustal magma reservoirs: trace element and Sr-Nd-O isotopic variations in two continental intraplate series at Monts Dore, Massif Central, France", *Chemical Geology*, 89, 281-303.
- Buffone, L., Lorenzoni, S., Pallara, M. and Zanettin, E. (1999): "Le macine rotatorie in rocce vulcaniche di Pompei", *Rivista di Studi Pompeiani*, 10, 117-130.
- Carmichael, I.S.E. (1965): "Trachytes and their feldspar phenocrysts", *Mineral Magazine* 34, 107-125.
- Caroff, M., Ambrics, C., Maury, R.-C. and Cotten, J. (1997): "From alkali basalt to phonolite in hand-size samples: vapor-differentiation effects in the Bouzentès lava flow (Cantal, France)", *Journal of Volcanology and Geothermal Research*, 79, 1-2, 47-61.
- Chauvel, C. and Jahn, B.M. (1984): "Nd-Sr isotope and REE geochemistry of alkali basalts from the Massif Central, France", *Geochimica et Cosmochimica Acta*, 48, 93-110.
- Chesworth W., Dejou, J. and Larroque, P. (1981): "The weathering of basalt and relative mobilities of the major elements at Belbex, France", *Geochimica et Cosmochimica Acta*, 45, 7, 1235-1243.
- Dautria, J.M., Liotard, J.M., Bosch, D. and Alard, O. (2010): "160Ma of sporadic basaltic activity on the Languedoc volcanic line (Southern France): A peculiar case of lithosphere-asthenosphere interplay", *Lithos*, 120, 1-2, 202-222.
- Dautria, J.M., Liotard, J.M. and Briot, D. (2004): "Particularités de la contamination crustale des phonolites: exemple du Velay oriental (Massif Central)", *Comptes Rendus Geoscience*, 336, 971-981.
- Dautria, J.-M. and Reille, J.-L. (1992): "Analyse pétrographique et détermination de la provenance du matériau basaltique de la provenance des meules antiques de Lattes", *Lattara*, 5, 233-237.
- Daveau, I., Chardenon, N., Da Costa, E., Dubesset, D., Henry, E. and Py, M. (2015): "Un port à Lattes avant Lattara ? Le village du Premier âge du Fer de 'La Cougourlude' (Hérault)", in: Olmer, F. and Roure R. (eds), *Les Gaulois au fil de l'eau, Actes du XXXVII^e colloque de l'Association pour l'étude de l'âge du Fer (Montpellier, 8-11 mai 2013)*, 1, Bordeaux: Ausonius Mémoires 39, 87-114.
- Daveau, I. and Py, M. (2015): "Grecs et Étrusques à Lattes : nouvelles données à partir des fouilles de la Cougourlude", in: Roure, R. (ed.), *Contacts et acculturations en Méditerranée occidentale: Hommages à Michel Bats. Actes du colloque d'Hyères (15-18 septembre 2011)*, Paris, Aix-en-Provence: Errance, Centre Camille-Jullian, 31-42.
- Downes, H. (1984): "Sr and Nd isotope geochemistry of coexisting alkaline magma series, Cantal, Massif Central, France", *Earth and Planetary Science Letters*, 69, 321-334.
- Gailledrat, E. (2015): "New Perspectives on *Emporia* in the Western Mediterranean: Greeks, Etruscans and Native Populations at the Mouth of the Lez (Hérault, France) during the Sixth-Fifth Centuries BC", *Journal of Mediterranean Archaeology*, 28-1, 23-50.
- Gailledrat E. and Vacheret, A. (2020): "Lattes/Lattara (Hérault), comptoir étrusque du littoral languedocien", *Gallia*, 77-2, <http://journals.openedition.org/gallia/5147>
- Garmy P. and Gailledrat E. (coords) (2015):, *Lattara (Lattes, Hérault), Rapport de fouille programmée, 2015*, SRA Languedoc-Roussillon, Montpellier.
- Hamelin, C., Seitz, H.-M., Barrat, J.-A., Dosso, L., Maury, R.C. and Chaussidon, M. (2009): "A low $\delta^7\text{Li}$ crustal component: Evidence from an alkali intraplate volcanic series (Chaîne des Puys, French Massif Central)", *Chemical Geology*, 266, 205-217.
- Hernandez, J. (1973): "Le volcanisme tertiaire des monts du Forez (Massif central français): basanites à analcime, à leucite et néphélinites à mëlilitite", *Bulletin de la Société Française de Minéralogie et de Cristallographie*, 96, 303-312.
- Janin T. and Py M. (coords) (2008): "Lattara/Lattes (Hérault), Nouveaux acquis, nouvelles questions sur une ville portuaire protohistorique et romaine", *Gallia*, 65, 1-230.
- Laj, C., Guillon, H. and Kissle, C. (2017): "Dynamics of the earth magnetic field in the 10-75 kyr period comprising the Laschamp and Mono Lake excursions: New results from the

- French Chaîne des Puys in a global perspective”, *Earth and Planetary Science Letters* 387, 184-197.
- Le Bas, M.J. Le Maitre, R.W., Streckeisen, A. and Zanettin, B. (1986): “A Chemical Classification of Volcanic Rocks based on the Total Alkali-Silica Diagram”, *Journal of Petrology*, 27 (3), 745-750.
- Lebeauvin, D., dir., (2014): *Les origines de Lattara et la présence étrusque. Les données de la zone*, 27, Lattes, ADAL, Lattara, 22.
- Legendre, C. Carroff, M., Leyrit, H., Nehlig, P. and Thieblemont, P. (2001): “Les premières phases d’édification du stratovolcan du Cantal (Massif central, France) entre 9,5 et 8,0 Ma; géologie et géochimie du secteur de l’Elnaceze. First stage of Cantal Stratovolcano growth (Central Massif, France) between 9.5 and 8.0 Ma; geology and geochemistry of the Elnaceze area”, *Comptes Rendus de l’Académie des Sciences - Series IIA - Earth and Planetary Science*, 332, 617-624.
- Lenoir, X., Dautria, J.M., Briquieu, L., Cantagrel, J.-M. and Lichard, A. (2000): “Nouvelles données géochronologiques, géochimiques et isotopiques sur le volcanisme du Forez: relation avec l’évolution cénozoïque du manteau du Massif Central”, *Comptes Rendus de l’Académie des Sciences - Series IIA - Earth and Planetary Science*, 330, 201-207.
- Liotard, J.M., Boivin, P., Cantagrel, J.-M. and Dupuy, C. (1983): “Amphibole Megacrysts and Associated Alkaline Basalts: Problems of their Petrogenetic and Geochemical Relationship”, *Bulletin de Minéralogie*, 106, 451-464.
- Liotard, J.M., Briot, D. and Boivin, P. (1988): “Petrological and geochemical relationships between pyroxene megacrysts and associated alkali-basalts from Massif Central”, *Contributions to Mineralogy and Petrology*, 98, 81-90.
- Liotard, J.M., Briquieu, L., Dautria, J.M. and Jakni, B. (1999): “Basanites et nephelinites du Bas-Languedoc (France): contamination crustale et hétérogénéité de la source mantellique”, *Bulletin de la Société Géologique de France*, 170, 423-433.
- Lustrino, M. and Wilson, M. (2007): “The circum-Mediterranean anorogenic Cenozoic igneous province”, *Earth-Science Reviews*, 81, 1-65.
- Martel, C. Champallier, R., Prouteau, G., Pichavant, M., Arbaret, L., Balcone-Boissard, H., Boudon, G., Boivin, P., Bourdier, J.-L. and Scaillet, B. (2013): “Trachyte Phase Relations and Implication for Magma Storage Conditions in the Chaîne des Puys (French Massif Central)”, *Journal of Petrology*, 54, 6, 1071-1107.
- Mauzy, R.C., Brousse, R., Villemant, B., Joron, J.-L., Jaffrezic, H. and Treuil, M. (1980): “Cristallisation fractionnée d’un magma basaltique alcalin: la série de la Chaîne des Puys (Massif Central, France)”, *Pétrologie. Bulletin de Minéralogie*, 103(2), 250-266.
- Oeser, M., Dohmen, R., Horn, I., Schuth, S. and Weyer, S. (2015): “Processes and time scales of magmatic evolution as revealed by Fe–Mg chemical and isotopic zoning in natural olivines”, *Geochimica et Cosmochimica Acta*, 154, 130-150.
- Paquette, J.-L. and Mergoïl, D.J. (2009): “Origin and U-Pb dating of zircon-bearing nepheline syenite xenoliths preserved in basaltic tephra (Massif Central, France)”, *Contributions to Mineralogy and Petrology*, 158, 245.
- Pilet, S., Hernandez, J., Sylvester, P. and Poujou, M. (2005): “The metasomatic alternative for ocean island basalt chemical heterogeneity”, *Earth and Planetary Science Letters*, 236, 148-166.
- Pilet, S., Hernandez, J. and Villemant, B. (2002): “Evidence for high silicic melt circulation and metasomatic events in the mantle beneath alkaline provinces: the Na-Fe-augitic green-core pyroxenes in the Tertiary alkali basalts of the Cantal Massif (French Massif Central)”, *Mineralogy and Petrology*, 76, 39-62.
- Py, M. (1992): “Meules d’époque protohistorique et romaine provenant de Lattes”, *Lattara*, 5, 183-232.
- Py, M. (2009): *Lattara, Lattes, Hérault. Comptoir gaulois méditerranéen entre Étrusques, Grecs et Romains*, Paris.
- Raux, S. (1999): “Les objets de la vie quotidienne à Lattes au IV^e siècle avant notre ère”, *Lattara*, 12, 446-514.
- Reille, J.L. (1999): “Détermination pétrographique de l’origine des meules de Lattes au I^{er} siècle av. notre ère. Changement et contraste des importations”, *Lattara*, 12, 520-522.
- Sørensen, H., Bernth, U. and Brousse, R. (1999): “Trachytes and phonolites from the Mont-Dore region, Auvergne, France”, *Geolines*, 9, 114-118.
- Villemant, B. and Treuil, M. (1983): “Comportement des éléments traces et majeurs dans la série alcaline du Velay; comparaison avec la Chaîne des Puys (Massif Central, France)”, *Bulletin de Minéralogie*, 106, 465-486.
- Wilson, M. and Downes, H. (1991): “Tertiary-Quaternary extension-related alkaline magmatism in western and central Europe”, *Journal of Petrology*, 32, 811-849.
- Wilson, M., Downes, H. and Cebria, J.M. (1995): “Contrasting fractionation trends in coexisting continental alkaline magma series; Cantal, Massif Central, France”, *Journal of Petrology*, 36, 1729-1753.
- Wilson, M. and Patterson, R. (2001): “Intraplate magmatism related to short-wavelength convective instabilities in the upper mantle: Evidence from the Tertiary-Quaternary volcanic province of Western and Central Europe”, in: Ernst, R. E. and Buchan, K.L. (eds), *Mantle plumes: their identification through time*. GSA Special Papers, 352, 37-58.

Table 1. Geochemical composition of the samples from Lattara and Cougourlude. Major elements LOI-free and 100% standardised.

Sample no.	Cougourlude					
	Fs 30230	Fs 30433	Fs 10379	Fs 10097	Si 4003	Us 4000
Rock type	basalt	hawaïte	hawaïte	basalt	basalt	Potassic trachy-basalt
SiO ₂ (wt%)	45.89	51.18	50.68	45.49	46.68	48.76
Al ₂ O ₃	14.34	15.42	14.42	13.24	13.14	16.80
Fe ₂ O ₃ (t)	12.48	10.08	10.94	13.45	12.53	11.59
MnO	0.19	0.11	0.13	0.19	0.18	0.19
MgO	7.40	5.54	6.72	7.78	9.33	4.77
CaO	10.60	9.29	9.38	10.91	10.45	9.02
Na ₂ O	4.04	3.87	3.52	3.71	3.20	3.66
K ₂ O	0.91	1.55	1.46	1.09	1.45	2.01
TiO ₂	3.28	2.34	2.20	3.15	2.33	2.54
P ₂ O ₅	0.88	0.62	0.55	1.00	0.72	0.66
LOI	1.58	0.71	1.08	2.09	0.37	1.27
Sc (µg/g)	18.3	21	20.8	18.5	21.1	16.5
V	232.6	174.1	163.5	215.7	192.5	191.6
Cr	229.6	610.9	308.2	256.5	328.5	107.6
Co	41	35.2	41.3	40.9	49.2	30.8
Ni	154.1	238.3	200.7	150.3	229.7	65.1
Cu	39.5	58.7	55.7	32.4	44.9	34.4
Zn	115.9	103.4	104.9	128.2	114.5	109.1
Ga	23.5	21	20.2	22.1	19.4	21.3
Rb	45.5	30.6	30.7	78.6	36.5	51.8
Sr	1146.5	621.6	594	1170.3	745.3	838.7
Y	33.4	24.8	27	31.7	29	32.1
Zr	394.1	191	187	346.1	206.3	335.4
Nb	129.2	56.4	53.3	119.7	71.7	101.8
Ba	994.2	483.9	447.7	849.6	617.8	740.1
Pb	3.9	4.2	6.7	6.1	5.8	5.5
Th	10.88	5.73	3.71	9.88	5.08	8.4
U	3.87	1.22	2.23	2.48	1.27	2.74

Sample no.	Cougourlude		Lattar		
	Fs 30230 Us 30779	Fs 20236	Us 53756 -1	Us 69347 -6	Us 69393 -1
Rock type	basalt	basalt	hawaïte	Tephri-phonolite	Tephri-phonolite
SiO ₂ (wt%)	50.07	46.20	46.46	52.22	51.90
Al ₂ O ₃	16.03	12.97	14.05	19.06	18.69
Fe ₂ O ₃ (t)	11.22	12.91	12.24	6.83	7.08
MnO	0.13	0.19	0.18	0.14	0.15
MgO	5.27	9.80	7.03	2.74	2.84
CaO	9.72	10.59	10.51	7.99	8.17
Na ₂ O	3.44	2.75	4.11	1.72	1.67
K ₂ O	0.82	1.44	1.25	8.31	8.50
TiO ₂	2.83	2.38	3.09	0.65	0.68
P ₂ O ₅	0.48	0.76	1.08	0.33	0.32
LOI	1.02	0.43	1.40	1.27	1.45

Sc (µg/g)	21.2	18	18.2	4.8	6.4
V	190.3	187.9	199.7	148.4	180.3
Cr	249.3	341.8	237.2	32.4	20.7
Co	33.3	46.8	44	15.7	21.6
Ni	100	259.5	140	21.8	21.3
Cu	33.3	50.3	34.7	40.4	53.5
Zn	128.1	117.8	127.2	66.8	72.2
Ga	23.8	19.9	24.1	18.5	18.8
Rb	10.3	35.3	54.5	499.9	448.7
Sr	522.9	804.5	1184.9	2197.8	2137.5
Y	29.7	29.4	33.1	38.3	37.5
Zr	176	219	343.9	336	341
Nb	37.1	77.6	121	20.9	22.2
Ba	313.1	684.2	864	1356.6	1433.6
Pb	5.1	4.6	7.7	101.9	95.2
Th	2.63	7.26	7.99	66.9	64.34
U	0.23	1.04	1.59	14.31	15.66

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