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The Acheulean site of la Noira (Centre region, France): Characterization of materials and alterations, choice of lacustrine millstone and evidence of anthropogenic behaviour

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ABSTRACT

The Acheulean site of la Noira was fossilized beneath the Fougères fluvial formation dated by the ESR method at 655 ± 55 ka. Coarse deposits were left at the base after the end of the Cher incision and served as raw material deposits for hominins. The occupation level has yielded bifaces, cores and a flake assemblage in lacustrine millstone. The systematic recording of about 6 500 lithic objects brought to light the reasons underlying the presence of the diverse materials, and elucidated hominin choice of lacustrine millstone for knapping flakes and shaping bifacial pieces. The systematic study of all the materials enabled us to advance hypotheses concerning some of the behaviour identified at the site: sorting of raw materials affected by frost, cursory peripheral knapping of slabs of up to a metre long with hammers weighing several kilogrammes, breaking up of large slabs over 10 cm long and displacement of the fragments. This analysis assesses hominin behaviour and the management and exploitation of raw material deposits at 700 ka.

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1. Introduction

The site of la Noira is located in the Centre of France, on the townland of Brinay, about 10 km south of Vierzon (Cher) (Fig. 1). It was discovered in 1972 by Jean Dépont during extractions from a fluvial formation known as the Fougères formation. He gathered several series of bifaces, cores and flake tools, knapped or manufactured in diverse siliceous materials, from several different levels (Dépont, 1984).

Geological and geochronological research has been conducted at the site since 2003 as part of prospecting authorized by the Ministry of Culture – Regional service of archaeology for the Centre of France. During surveys, sampling or test pits, bifaces, cores and flakes in lacustrine millstone were systematically found in association with coarse elements in the conglomerates at the base of the

fluvial formation, generally in cryoturbation cells (Despriée et al., 2007).

An *in situ* archaeological level was identified at the base of the sequence, below the Fougères alluvial apron (sheet D, +13/21 m rel., south log, Fig. 2). Excavations carried out from 2011 to 2014 as part of the PremAcheuSept ANR uncovered this level over a surface of 100 m². It appears to be the only preserved level after extraction works. The artefacts associated with coarse elements and blocks are bifaces, cores and flakes attributed to the Acheulean, providing evidence of sporadic arrivals of bifacial technology in Western Europe from 700 ka (Moncel et al., 2013, *in press*).

The only siliceous raw material used in the archaeological level is lacustrine millstone. This material appears to have been collected *in situ*. In Early Pleistocene (Oldowan, Mode 1 or core-and-flake industry) sites in France and Europe, one or several varieties of rock available on-site were generally used. They were gathered then knapped on-site by hominins or else collected in the immediate vicinity of the site (Lumley et al., 1988, 2005; Carbonell et al., 1995, 1999; Peretto et al., 1998; Despriée et al., 2006, 2009;

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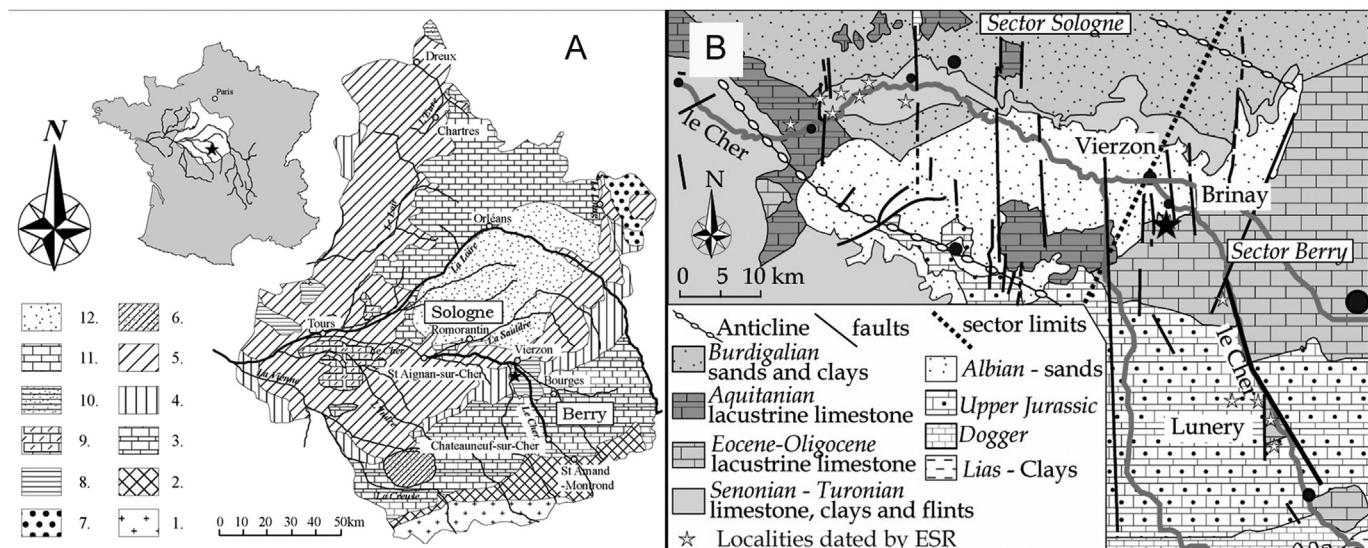


Fig. 1. A. Maps showing the location of the site of la Noira at Brinay, near the geographic centre of France, about 10 km south of Vierzon. B. The archaeological level is fossilized on the west slope of the Cher Valley, which cuts into the Berry lacustrine limestones in this area.

Arzarello et al., 2009; Toro-Moyano et al., 2010; Mgeladze et al., 2011; Garcia et al., 2013; Barsky et al., 2014). The same appears to apply to some of the earliest known Acheulean sites in the Mediterranean zone (Mosquera et al., 2015).

This is the case at the site of la Noira where the use of lacustrine millstone at the base of the sequence (unit a, stratum a) appears to be original. This paper aims to identify the parameters underlying the choice of this raw material, which is mixed with many other rock types, to ascertain the sought-after blank types and to describe the modifications by comparing the visible marks with those obtained during experiments on the same raw materials.

2. The site of Brinay-la Noira

The site of la Noira is located in the middle of the west slope of the Cher Valley, beneath the D sheet (at a relative altitude of 13/+21 m above the present-day base layer). The sedimentary sequence was deposited in an alluvial plain context and contains four units of rudites and arenites (from the base to the top, Fig. 2). First of all, a conglomerate was deposited in two phases and reaches a maximum thickness of about 50 cm (unit a or stratum a). In discordance on an Oligocene lacustrine limestone floor, slabs of millstone, blocks, stones and gravels in diverse rocks are surrounded by a sandy-clayey matrix. This conglomerate was deposited after the end of river incision, at the beginning of a glacial period, and underwent cryoturbation in places, as did the altered limestone level, during the glacial maximum (Despriée et al., 2007). The whole complex was covered by sand lenses organized into characteristic fluviatile deposits (unit b). Then, after a standstill phase in terms of sedimentation and erosion, a second conglomerate deposited in discordance (unit c) was covered by a sandy-silty slope deposit (unit d). ESR measurements on optically bleached sand from unit b gave a weighted average age of 655 ka ± 55 ka (Voinchet et al., 2010; Moncel et al., 2013, in press).

3. Unit a: accumulations of blocks and stones

The top of the lacustrine limestone floor is altered into whorled clay. In the excavated part, this is present as a platform (squares A to E, 0 to 2), surrounded in the north and the south by two hollows. Two accumulations of blocks and stones with a maximum

thickness of 50 cm were recovered from this platform. They continue towards the west behind the profile. To the east (bands 4 to 9), they are rather regularly spread over the whole surface, with an average thickness of 10 cm (Fig. 3). A total of 6 495 lithic objects were systematically recorded during successive dismantling by overhead photography according to the metric grid. The photographs were printed at a scale of 1/10 and used for recording all the characteristics of the lithic object (raw material, type dimensions), spatial position (orientation and dip) and visible alterations (physical, chemical, climatic). These data were verified in the laboratory before being entered into the database. All the lithic elements were then redrawn for the various distribution studies and particularly for the taphonomic study.

3.1. Taphonomic study

The aim of the taphonomic study was to bring to light characteristics elucidating the natural or anthropogenic deposition conditions of these accumulations and to detect any possible reworking. The high number of recorded pieces enables us to statistically corroborate observations and back up hypotheses before validation through experiments.

The lithic objects in subhorizontal position and with a slight dip (<10°) are the most frequent. They are accumulated in several layers, with the base of the heap lying directly on the clay. The number of blocks lying vertically and on their sides is 888 (13.7%). Note the total absence of clustering in pockets and spatial distribution does not indicate organization in polygons, as shown in the other sectors (Despriée et al., 2007). This seems to indicate that the rare vertical positions of objects could result from the natural deposition of stones between larger elements. Approximately 60% of the upright pieces are less than 100 mm long and 72% are less than 100 mm wide (Fig. 3).

3.2. Slab and stone morphology and alterations

Varied rock types are present in unit a, but visual petrographic identification was difficult on account of uniform surface colouring by iron oxides. This identification is however essential in order to determine the origin of these rocks and to reconstruct the history of their transport to the site. For the non-knapped elements,

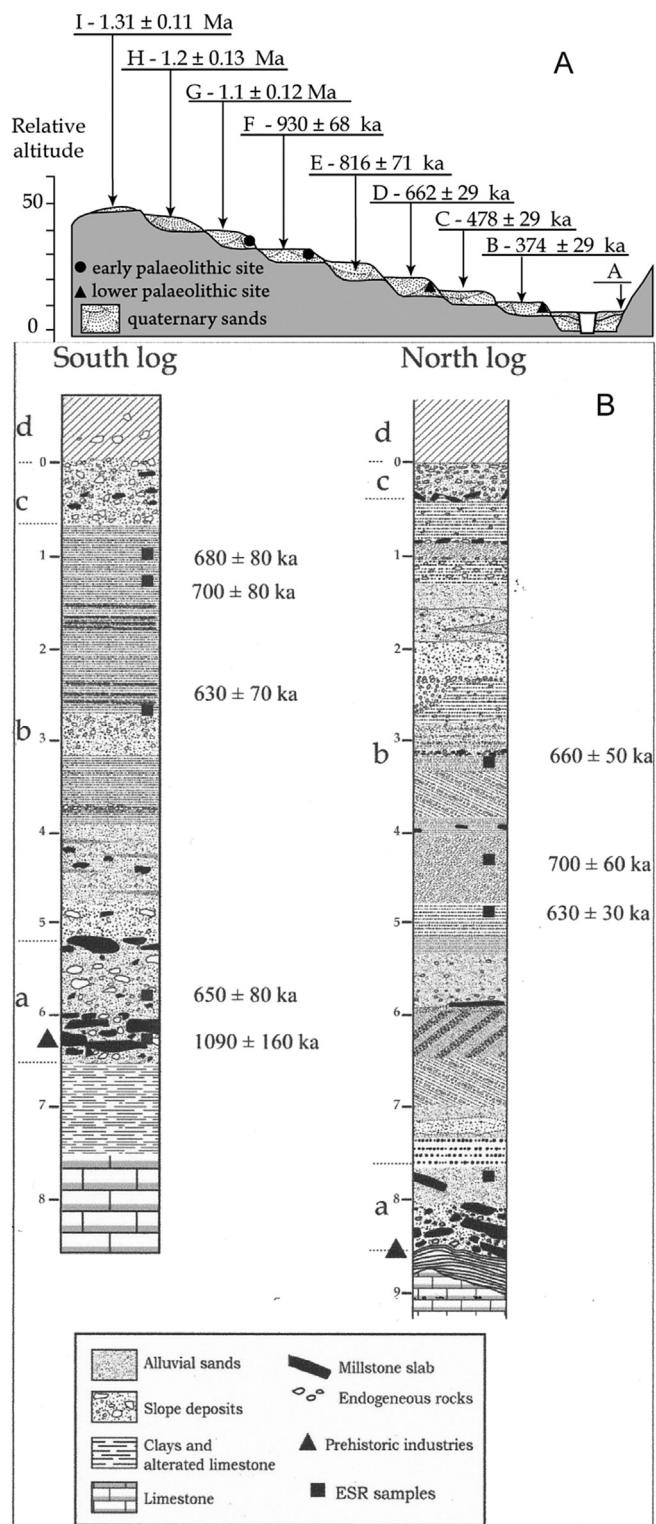


Fig. 2. A. Theoretical model of the fluvatile system of the middle valley of the Cher and ESR ages of the fluvatile formations. The relative position of the Fougeres fluvatile formation and the site of la Noira are indicated by a star. B. North and south stratigraphic logs from the west section of the la Noira quarry and position of the dating samples.

petrographic identification was thus carried out on fresh breaks. For the knapped materials, observations were conducted with a broad view magnifying lamp (170 mm) with magnifications of $\times 3$ and $\times 12$ diopters.

The identified materials are endogenous rocks such as granite and quartz (13.4%) and more varied sedimentary rocks, such as sandstones (3.8%), Jurassic cherts (17.1%), lacustrine millstone (48.2%), Quincyte (18.2%) and iron ore.

Among the endogenous rocks, real pebble shapes and subspherical or subovoid volumes are rare. Conversely, irregular polyhedral volumes with numerous fractures and use marks are abundant. Pebbles, cobbles and blocks (after Wentworth, 1922; Cojan and Renard, 2006) bear concave–convex used surfaces and blunted ridges with sharp crushed edges. All these marks indicate that the rocks underwent repeated high energy fluvatile-type transport. 35% of them present chemical alterations characteristic of tropical climates, with enrichments in iron and aluminium and significant recrystallizations. Breaks or sections in the blocks and stones showed that the iron oxides often penetrated deep down.

Lacustrine millstones (48.2% of the identified rocks) are the only slab materials that generally do not bear the transport marks observed on the other rocks. The siliceous millstone elements are described below.

The potential sources of the rudites unearthed at the base of la Noira were located on the basis of petrographic types, morphologies and marks. Stones and blocks with the same petrographic varieties, the same morphologies and sizes, were observed spread out on the plateau from the edge of the Massif Central to Vierzon. These detrital deposits also fill paleo-channels between Montluçon and Vierzon (Debrand-Passard et al., 1978; Lablanche et al., 1984; Larue and Etienne, 1998). Apart from the siliceous millstones, these rocks were thus transported from upstream over distances ranging from 60 to 120 km (Fig. 4).

During the development of Quaternary drainage, incision-related erosion dismantled these detrital deposits. At the present time, they are of limited thickness (1.50 m–3 m) and only subsist at the top of interfluves. They are continuously visible in particular on the left bank of the Cher at the Cher-Arnon interfluvium (Fig. 5). Erosion also often removed the clayey-sandy matrix and the large elements were thus left directly on the limestone substratum and slid onto the slopes (Debrand-Passard et al., 1978; Lablanche et al., 1994; Manivit et al., 1994). Some of them also underwent frost action (29.5%) and were moved once again during cold phases.

4. Lacustrine silicifications in unit a (stratum a)

Although all the blocks and stones from unit a bear traces of high competency transport and significant chemical and/or climatic alterations that can affect the whole thickness of the material, the same does not apply to the millstone slabs in this level. This is due to the local origin and limited transport of this raw material. During the Quaternary, the Cher and its two main tributaries of the Berry, the Yèvre and the Arnon, cut into the western edge of the Berry Limestones that filled the Mehun-sur-Yèvre Paleogene lacustrine basin in the Brinay sector, exposing the levels containing the silicifications called millstone slabs (Fig. 5).

Millstone slabs forms as a result of the concentration of silica in lacustrine limestone during successive diagenesis. The silica is concentrated into decimetric to metric-sized slabs. The flattened section ends in a cortical V or U-shaped perimeter. This phenomenon fossilized original facies of diverse types of deposits: we observe banded or vermiculated algal and stromatolitic deposits, breccia structures, with cavities (burrows) and tubes (imprints of roots and plant debris). These cavities and irregularities remain very visible in the silicifications and affect their homogeneity (Debrand-Passard et al., 1978; Lablanche, 1982).

These silicifications are in a horizontal position in the upper part of the carbonated formations accumulated in the lacustrine basin of Mehun-sur-Yèvre (Person et al., 1994). They are present in the high

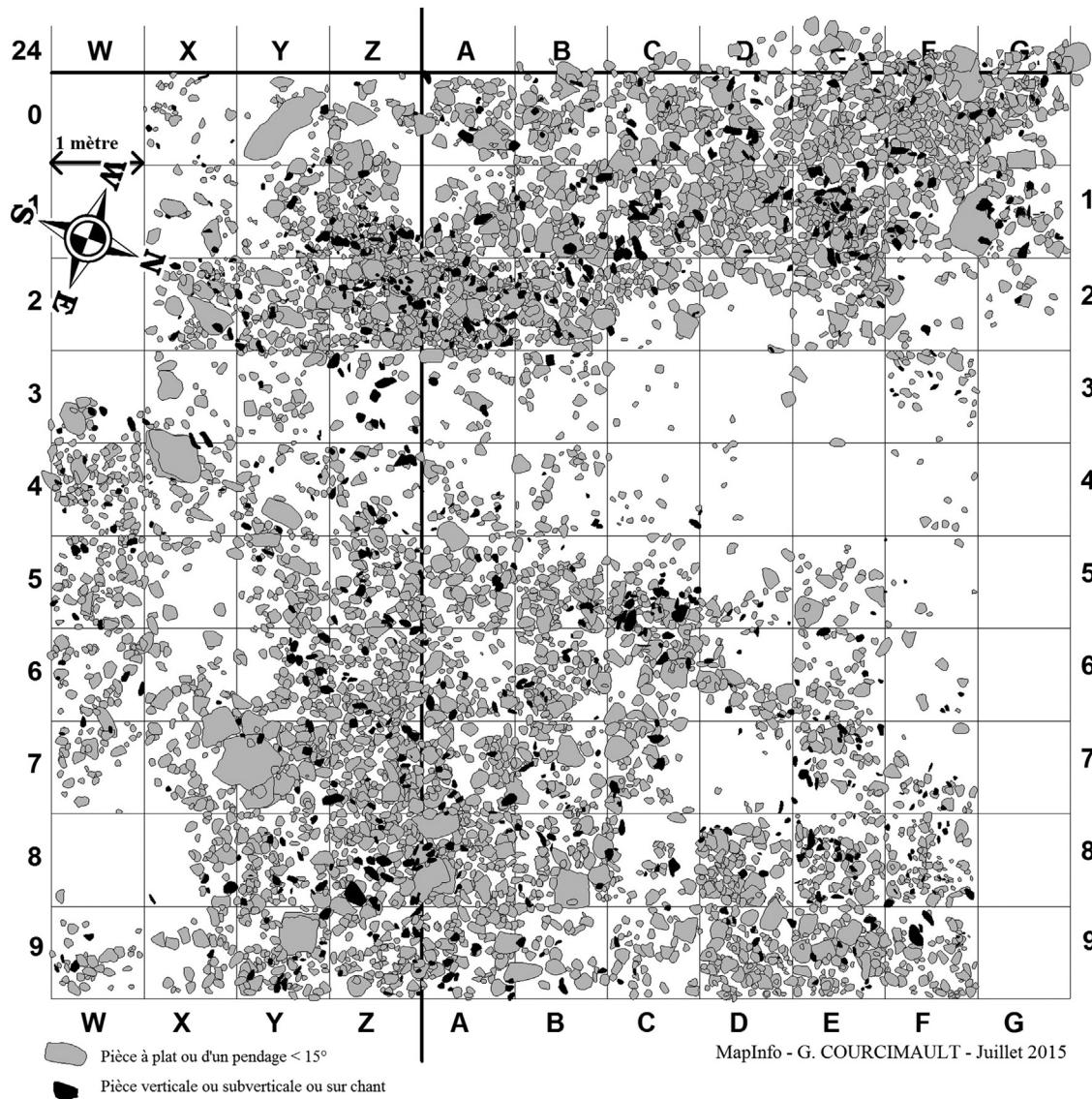


Fig. 3. Distribution plot of the 6495 blocks and stones from unit a lying on the altered lacustrine limestone layer. The random distribution of the vertical stones appears to be size-related. It does not indicate organization linked to cryoturbation, as observed during surveys to the north and east of the excavated sector.

part of the slope overlooking the site. They were observed in the trenches cutting into the lacustrine limestone in the upper part of the Buisson-Long compartment (Fig. 5). Erosion by the Cher on the western edge of the lacustrine basin exposed the slabs, which were then moved down by gravity after each phase of incision. Some of them are still visible in an oblique position on the slope 500 m south of la Noira. At la Noira, the altitude of the incision floor is close to that of the base of the lacustrine limestones (Fig. 5, transect) and no slabs were discovered during mechanical trenching in the altered limestone.

4.1. Millstone slabs, fragments and slab debris

During the excavation of unit a, 3127 fragments of millstone slabs were recorded, representing 48.2% of the rudites. As the presence of these millstone slabs, fragments and debris is directly linked to river incision at the beginning of the glacial phase, we systematically looked for visible traces of climatic alterations on the surface of millstone slab fragments.

4.1.1. Gelification marks on millstone slabs and distribution in unit a

Millstone is a microporous siliceous rock that can thus be frost-fractured (Vatan, 1967; Pommerol et al., 2015). 1272 slabs, fragments or debris, or 41%, bear traces of frost-weathering. These consist of surface pits ranging in size from several centimetres to several decimetres. Gelification can sometimes affect the total thickness of the slabs and forms multidirectional fissures and/or irregular breaks along the edges. If the frost-fractured slab undergoes the slightest shock, it breaks into countless orthogonal fragments with cutting ridges and sharp splinters.

The presence of diverse categories of markers implies that several periods of gelification occurred (Fig. 6):

- the surfaces and mass are entirely frost-fractured. Scars of pit-shaped removals and breaks are covered by an orange to rust-coloured patina. Ridges are blunted and already incomplete blocks break easily. Gelification occurred before deposition at the site. Pits and debris were removed during transport and patinas were also acquired beforehand. The last phase of

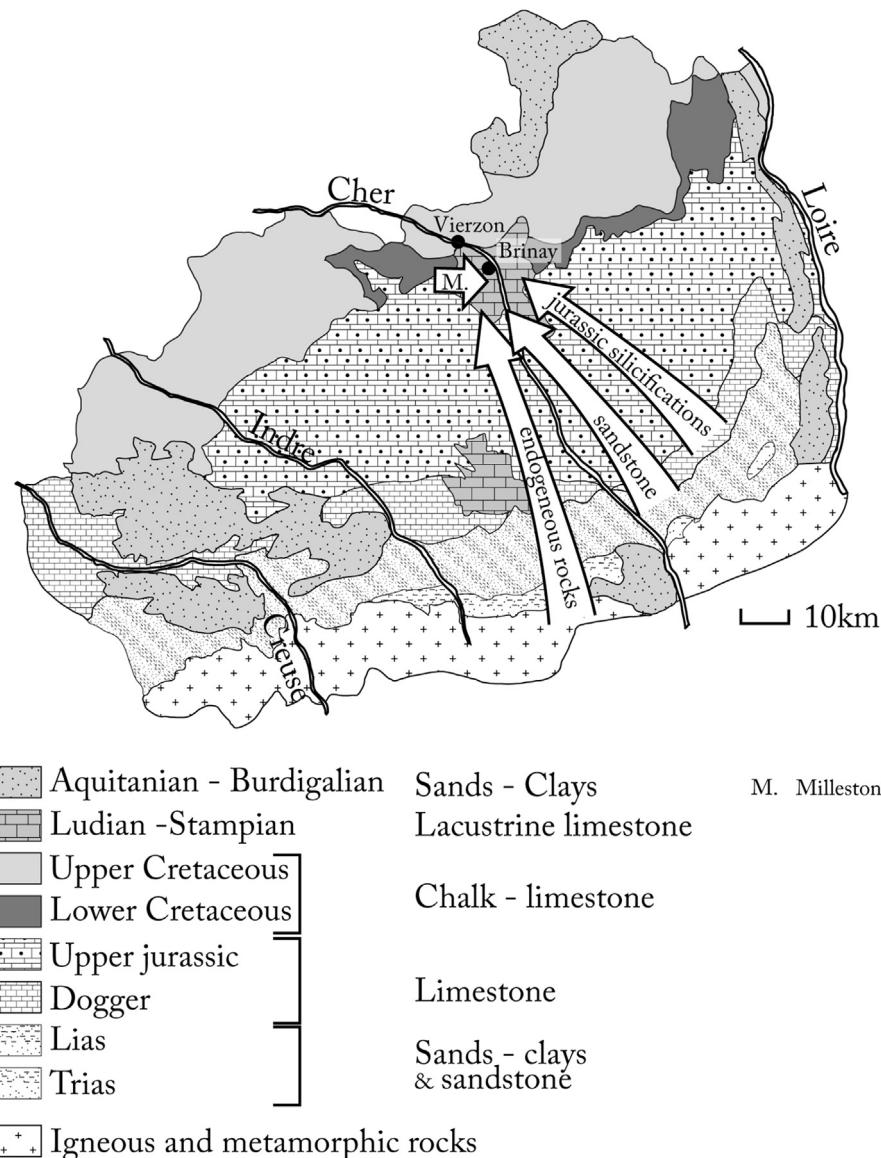


Fig. 4. Simplified map of the primary, secondary and Tertiary formations crossed from south to north by the Cher Valley upstream of Vierzon. These formations are the sources of the different rocks spread out during regional Tertiary peneplanation and still present on the interfluves.

gelification occurred on-site before burial, which explains the dislocation of the pieces at the time of their discovery. The debris separate when manipulated or exposed to a slight shock (Fig. 6A);

- surfaces bear fresh or non-detached pit-shaped removals, rare fresh breaks and, at times, not very visible fissures. The sonority produced by a shock is muted and the block only breaks after a violent shock. Gelification occurred once the piece was transported to the site and before burial beneath the sandy sequences, which resulted in the conservation of the perceived wholeness of the pieces and the absence of patina (Fig. 6B);
- only the upward-facing cortical surface is altered by abundant small coalescent flakes still in place. These are only removed when the piece is manipulated. The mass of the piece is not frost-fractured. Close examination does not reveal the presence of fissures. *Hypothesis:* Slight gelification of the porous and fragile upper cortical surface of the already *in situ* piece protected by the sandy-gravelly deposits covering the site in this area, resulted in the conservation of frost flakes in place.

All of the millstone slabs and slab fragments, regardless of whether they underwent gelification, present very similar distributions on the surface and further down, in both accumulations and right across the rest of the excavated surface (Fig. 7). Hominins thus chose raw materials that could be used from this mixture of slabs and slab fragments, bearing the marks of several phases of gelification, along with recently exposed siliceous limestones.

Frost-fractured slabs are not apt for knapping or shaping but non-frost-fractured siliceous slabs and fragments can be considered as possible blanks for biface shaping or flaking, as shown by the slabs and fragments with one or several cortical removals or traces of unifacial or bifacial shaping (Moncel et al., 2013).

4.1.2. Distribution of the non-frost-shattered slabs and slab fragments

The non-frost-fractured elements are slabs of about a metre in size, some of which are whole and some of which were formerly broken and patinated, slab fragments (width ≥ 10 cm) and slab

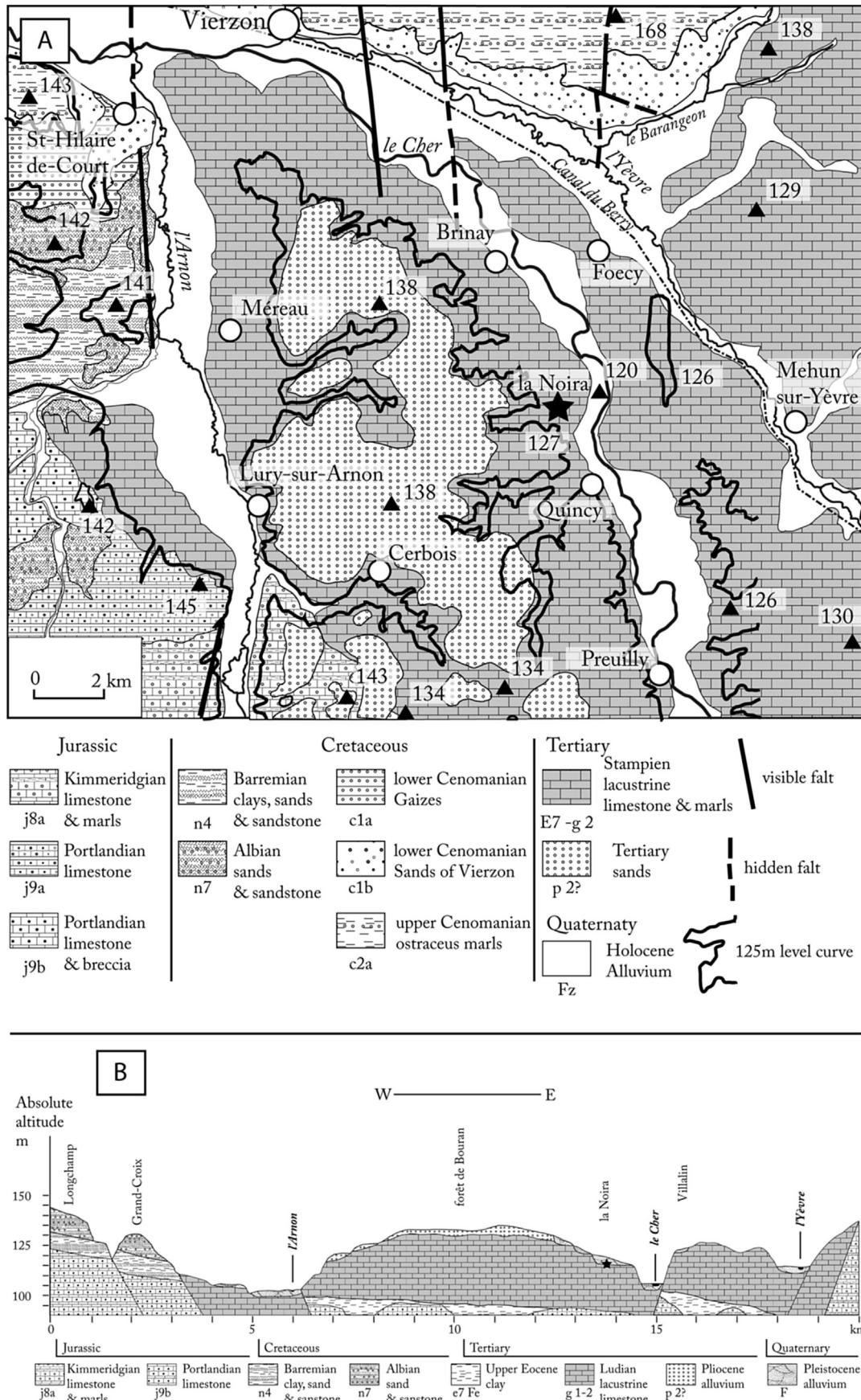


Fig. 5. The Acheulean site of la Noira is located in a zone of contact between Jurassic marine limestones to the south, Lower Cretaceous (Albian) sandy-clayey deposits to the west, Upper Cretaceous (Cenomanian to Turonian) marls, gaizes and sands to the north, and the Eocene-Oligocene lacustrine basin to the east.



Fig. 6. Fragments of frost-fractured millstone slabs. A: gelification before transport to the site, the removal scars are covered by an orangey patina. B: gelification after transport to the site, with multidirectional fissures, piece deriving from a cryoturbation polygon. C: intact slab with only cortical micro-pits (Photos G. Courcimault and J. Despriée).

debris (width < 10 cm) partially delimited by a cortical perimeter and edges resulting from a “fresh” orthogonal break with no patina, alteration or signs of transport. The distribution plot of non-frost-fractured siliceous limestone elements brings to light accumulations of whole slabs, fragments and debris around several slabs of about a metre, associated with large pebbles, used blocks and artefacts (bifacial pieces, flakes, cores; Fig. 8).

4.2. Slabs up to 1 m long

Five often fragmented slabs or slab fragments measuring several decimetres and up to a metre were unearthed at the excavation. The fragments, colours and different thickness are at times clustered together (Fig. 9, A1). The cortical perimeter of these slabs has totally disappeared, replaced with a polygonal perimeter formed by

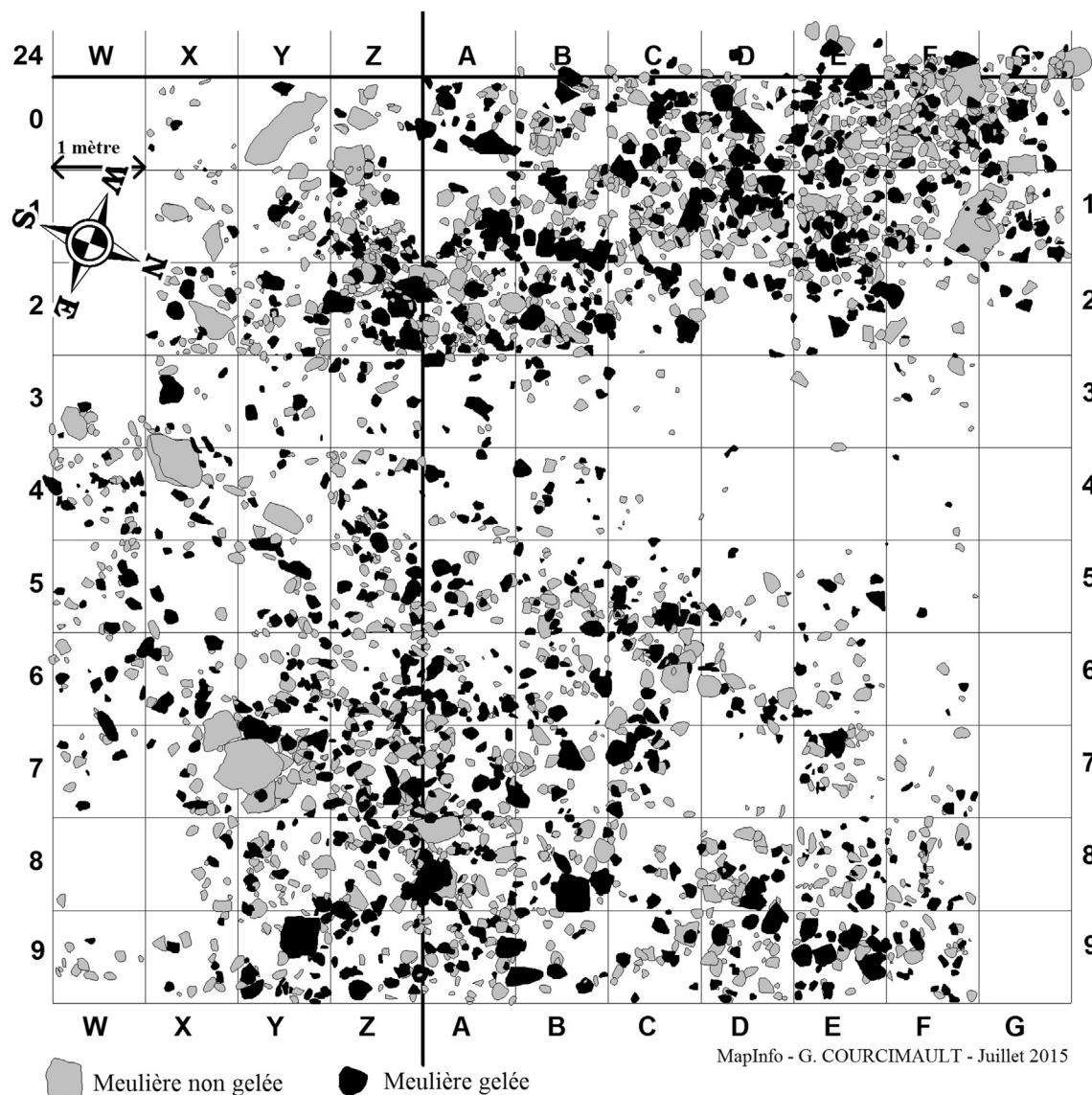


Fig. 7. Distribution of the frost-fractured or non-frost-fractured siliceous limestone slabs, plates, fragments and debris.

a sequence of orthogonal sides (Fig. 9, A2) displaying homogeneous silicification, with no patina or alteration. On the edges, traces of shocks are observed at the top of the sharp or inverted angles around the perimeter. The ridges do not bear blunting or crushing marks. Several deformations of the cortex are observed on the periphery or on the upper surface.

No fragments refitting onto these slabs were found in place or in the immediate vicinity. However, at times, several fragments of the same slab are still in connection (Fig. 9, B1) and cortex crushing is clearly visible at the centre of the two broken edges (Fig. 9, B2).

4.3. Decimetric-sized slabs and slab fragments

4.3.1. Whole slabs

There are a total of 241 decimetric-sized whole or partial slabs with patinated edges. The whole slabs are characterized by the presence of cortex on the totality of both relatively convex and flattened surfaces, with an intact cortical perimeter with a V and/or U-shaped profile. The partial slab fragments with edges forming

part of the perimeter are covered by a glossy orangey patina masking the original siliceous material. The presence of shocks on the surfaces, considerable blunting of the ridges, crushing of the sharp-angled edges and splintering of the sides show that these breaks occurred before transport to the site and that they bear the marks of some degree of transport.

4.3.2. Fragments and slab debris

The totality of the relatively used cortex is conserved on both surfaces of the 173 slab fragments ($L \geq 10$ cm) and 153 slab debris ($l < 10$ cm). On the non-patinated sides, the siliceous material is clearly visible without patina or transport marks and with no traces of blunting or crushing of the ridges.

- Volume of slabs, fragments and debris

As a result of the irregular thickness of the original silicifications, whole or patinated slab volumes are generally prismatic, with non-parallel cortical surfaces and sub-triangular or trapezoidal cross-

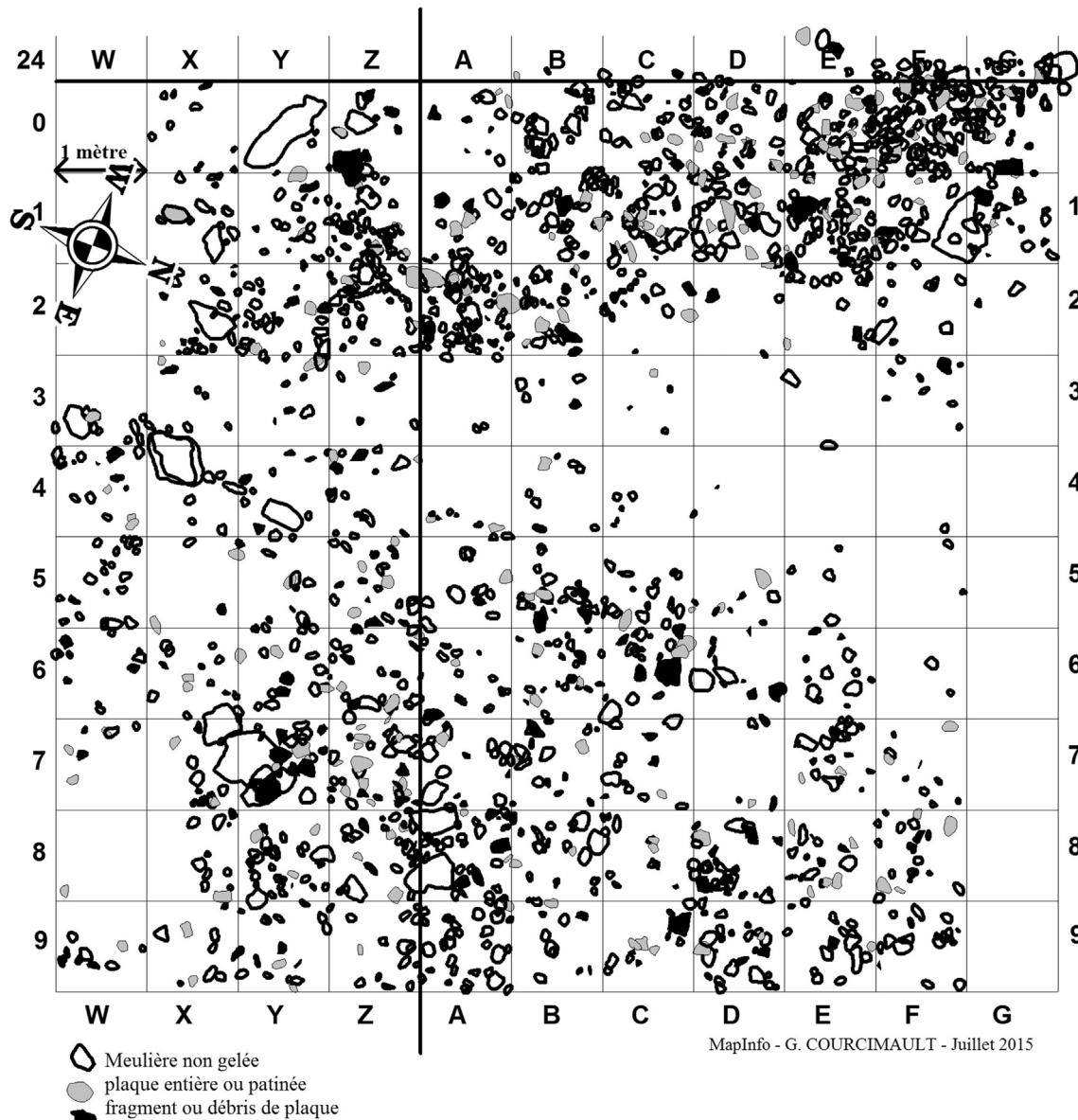


Fig. 8. Distribution of the millstone elements with no evidence of climatic alteration. Note the association of the heaps and the decimetric-sized to metre-sized slabs.



Fig. 9. A1 and B1: heaps of decimetric-sized to metre-sized slabs; A2: the perimeter is limited by orthogonal edges with characteristic angulations and impact marks. B2: detail of the broken upper slab, with crushing of the cortex (photo G. Courcinault).

sections. The volumes of the slab fragments are closer to parallel-epipeds with sub-vertical sides with 80–90° angles, and sub-trapezoidal or sub-rectangular sections. The perimeter of these fragments is an irregular polygon. Ovoid [Table 1](#).

Table 1
Morphology of decametric-sized slabs and slab fragments of millstone.

Volumes	Slabs	%	Fragments	%
Prismatic	125	51.9	175	53.7
Parallelepiped	36	14.9	90	27.6
Ovoid	37	15.3	13	4.0
Dome-shaped	29	12.3	36	11.0
Polyhedrons and indeterminates	14	05.6	12	3.7
	241	100.0	326	100.0

- Dimensions of whole slabs and fragments

The lengths of virtually all of the slab fragments and debris (98.2%) range between 50 and 260 mm, but for three-quarters of the pieces (77%), length ranges from 100 to 150 mm. Average length is 143 mm. Width ranges from 40 to 200 mm (96.6%), with an average width of 106 cm, and for 79% of the pieces, width varies from 100 to 150 mm. Average elongation is 1.3 L/W ([Fig. 10](#)). In spite of the systematic recording of all the siliceous limestone elements, no smaller elements were uncovered during the excavation ([Fig. 10](#)).

Thickness varies between 20 and 100 mm (97.9%). Average thickness is 51 mm and for 79% of the fragments, thickness ranges from 30 to 70 mm ([Table 2](#)). The elongation index (L/W) for most of the pieces (315/329, or 95.7%) varies between 1 and 2, indicating

the sole presence of wide, thick and quite thick modules (after Morphologie descriptive, In: [Leroi-Gourhan et al., 1966](#)).

Table 2

Thickness of slabs and slab fragments of millstone.

Slabs	W/H ratios	Number	%
Thick	$1 \leq W/H \leq 1.99$	146	44.4
Quite thick	$2 \leq W/H \leq 2.99$	141	42.9
Quite thin	$3 \leq W/H \leq 3.99$	30	9.1
Thin	$4 \leq W/H \leq 5.99$	12	3.6
		326	100.0

A total of 567 elements with no frost alteration marks in the mass of the piece are thus apt for knapping and shaping. Their average and higher dimensions are in keeping with the average dimensions of the cores and bifacial artefacts found on site ([Moncel et al., 2013, in press](#)). These fragments with rather calibrated dimensions, with sides corresponding to non-patinated breaks with no traces of transport, point towards the hypothesis of intentional fracturing, with a view to possible anthropogenic action.

- Marks on slab fragments

Slab fragments with a non-patinated side are predominant ([Table 3](#)). The position of this sole non-patinated side on a cortical perimeter appears to indicate that the original slab was broken into two parts ([Fig. 11A and B](#)). On a quarter of the fragments two sides are non-patinated ([Fig. 11C](#)). Another quarter of the pieces are slabs with several non-patinated sides forming a polygonal perimeter ([Fig. 11D](#)).

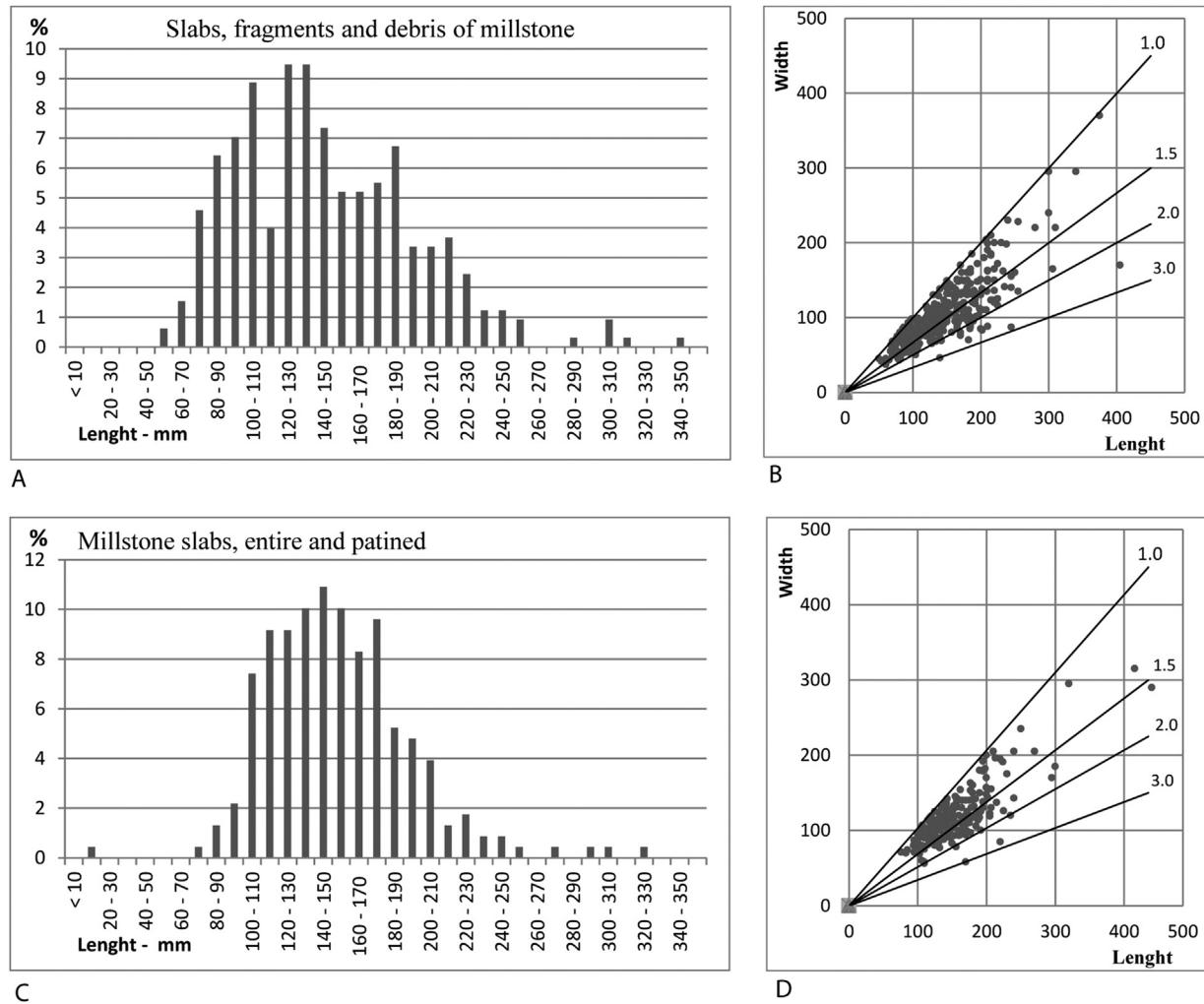


Fig. 10. Dimensions and modules of the millstone slabs, fragments and debris.

Table 3

Proportion of non-patinated sides of the millstone slab fragments.

Number of non-patinated sides/slab	Number of slab fragments	%
1	72	41.6
2	45	26.0
3	24	13.9
4	25	14.4
5	6	03.5
6	1	00.6
	173	100.00

Marks potentially related to intentional breaks were systematically recorded and characterized for each slab fragment: impact marks, crushing, fissures, breaks... In this way, 370 sides were examined on the 173 slab fragments with a magnifying lamp.

Some marks are located on the edge of non-patinated edges with non-patinated breaks. Others bear characteristic hard hammer impact marks, with circular depressions in the raw material. Ridges, satellite removals and splinters are observed on the edge at the impact point. Crushing marks measuring about a centimetre are present on the cortical zone, on the edges, at times exposing the underlying silica, with fissures. In some cases, these marks are visible on opposite surfaces (Figs. 11 and 12).

The angles were measured on the surfaces bearing impact or crushing marks. They range between 80 and 100° (%) and indicate sides with an orthogonal surface in relation to the original slab surfaces (Fig. 12). The fracture line is rectilinear (angle = 170–190°: 37.4%), or presents an internal angle at the impact mark (angle < 170°: 21.9%) or more generally an outer angle (angle > 190°: 40.6%) (Figs. 12 and 13).

4.4. Used blocks and pebbles associated with broken slabs

The multiple marks present on the non-patinated slab sides point to intentional breakage with a sufficiently heavyweight hard hammer to break the large slabs. Used blocks or quartz and granite pebbles, as well as fragments of Jurassic siliceous nodules and laterritised millstone, were recovered in the immediate vicinity of each of these accumulations (Fig. 14). In this way, 48 pieces were recorded, characterized by extreme hardness, unlike the other deeply altered or frost-fractured granites, quartz and Jurassic silicifications.

These pieces include about ten used blocks and pebbles weighing more than 2 kg and up to 3, 4 and 5 kg, with an average length of 180 mm, an average width of 140 mm and a thickness of 100 mm. They are generally ovoid or prismatic. The irregular surfaces are patinated by iron oxides and bear the physical and chemical marks of long transport. Generally, one of the ends is

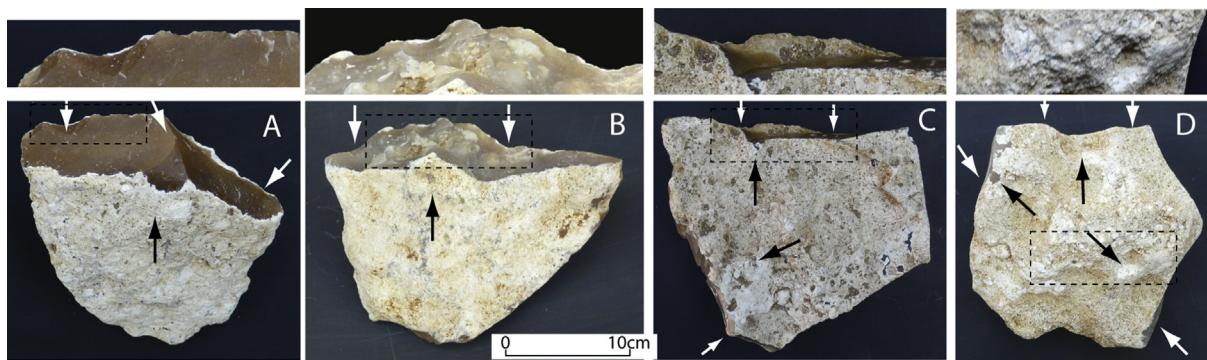


Fig. 11. Archaeological broken slabs. The fresh broken edges form internal or external angles with a pit removal visible at the top of the angle (A), with crushing of the cortex (B), with an impact (C) on the upper surface, and multiple crushing marks on the lower surface (D) (photo J. Despriée). Black arrows indicate the location of the shock. The white arrows indicate the opposite shock on the lower slab face. The upper photos indicate details corresponding to the dotted squares: A and B micro-scars due to the opposite shock, C crack and breakage, D cortical surface crushed and micro-scars of the cortex deleted. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

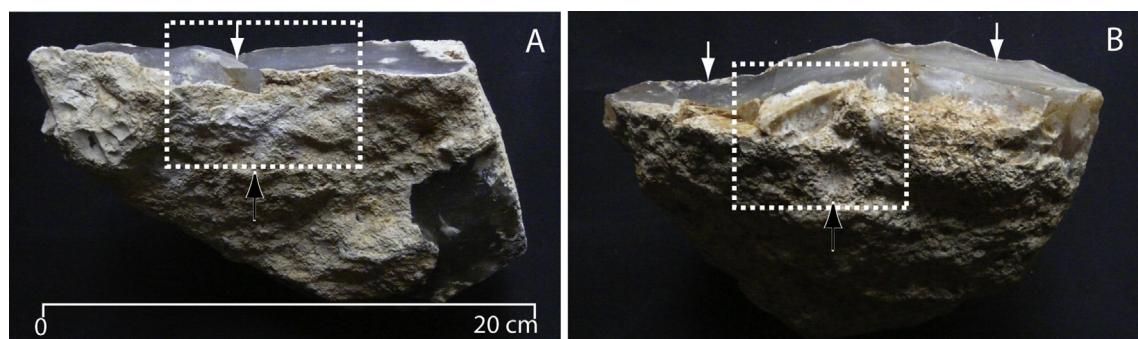


Fig. 12. Archaeological broken slab fragments showing the edge (upper part), marked crushing of the cortex at the impact zone with a ridge and a satellite scra due to the shock (photos J. Despriée). The black arrows indicate the location of the shocks. The white arrows indicate the opposite shocks. The dotted squares focus on the large crushed areas. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

regularly convex. On one or several zones of these ends, the iron oxides have disappeared, and splintering, crushing and pitting are visible in some cases. However, a close examination of the surfaces does not reveal any significant impact marks similar to those typically observed on hard hammers used for long periods (Fig. 15).

5. Experiments and comparisons

Experiments have been performed on ten unworked millstone slabs recovered in the quarry, similar to the slabs found on the excavations.

On the excavated area, the average sizes of the slabs fragments considered as resulting of an anthropic breakage are of $143 \times 106 \times 51$ mm. Since the lacustrine slabs found on their geological outcrops or on the slopes up to the site are larger ($500\text{--}400 \times 300\text{--}200$ mm), we may assume that the slabs knapped by hominins were at least double in surface.

5.1. Entire slabs

The selected slabs are exempt of physical, chemical or climatic alteration and were recovered in unit a during surveys in different areas of the site. Quartz and granite hammers were conserved in the same conditions. A tarpaulin was laid down to retrieve all the fragments and debris produced during the shock (Fig. 16).

Trials were carried out on totally cortical slabs or slabs with patinated edges. Slabs with plane and subparallel surfaces were laid flat on the ground (Fig. 16A). Slabs with a slightly curved profile were placed with the convex surface facing upwards and downwards during trials.

The trials showed the importance of two factors: slab concavity/concavity and slab thickness (Table 4). The other trials were carried out on an anvil, a Jurassic siliceous block identical to the one found during the excavation. The number of blows necessary for fragmenting the blocks was noted, as well as the resulting.

Table 4
Experimental data for the different types of experiments.

Experiments	Surfaces	Dimensions	Weight	Breakage	Position	Cortex thickness	Results and marks
1	Plane	$260 \times 170 \times 40$	3 470 g	1 blow	Centre	1 mm	2 fg, crushing, ridge
2	Plane	$240 \times 140 \times 50$	2 530 g	1 blow	Centre	1.5 mm	2 fg, impact, ridge, fissure, lip
3a	Convex	$380 \times 210 \times 70$	7 730 g	5 blows	+ thick	3 mm	Crushing, no breakage
3b	Concave	$380 \times 210 \times 70$	7 730 g	3 blows	+ thick	3 mm	2 fg, crushing, ridges
4a	Convex	$360 \times 220 \times 50$	5 315 g	3 blows	$\frac{1}{4}$ upper	6 mm	1 fg, 2 debris, crushing, 1 counter-blow
4a	Concave	$360 \times 220 \times 50$	5 315 g	2 blows	$\frac{1}{4}$ lateral $\frac{1}{4}$ lower	6 mm	1 fg polygonal, 3 debris
5	On anvil	$260 \times 160 \times 85$	3 785 g	2 blows	Centre	3 mm	2 fg polygonal, 1 debris 2 counter-blow
6	On anvil	$245 \times 190 \times 45$	2 985 g	1 blow	Centre	3 mm	2 fragments, crushing

fg = fragment.

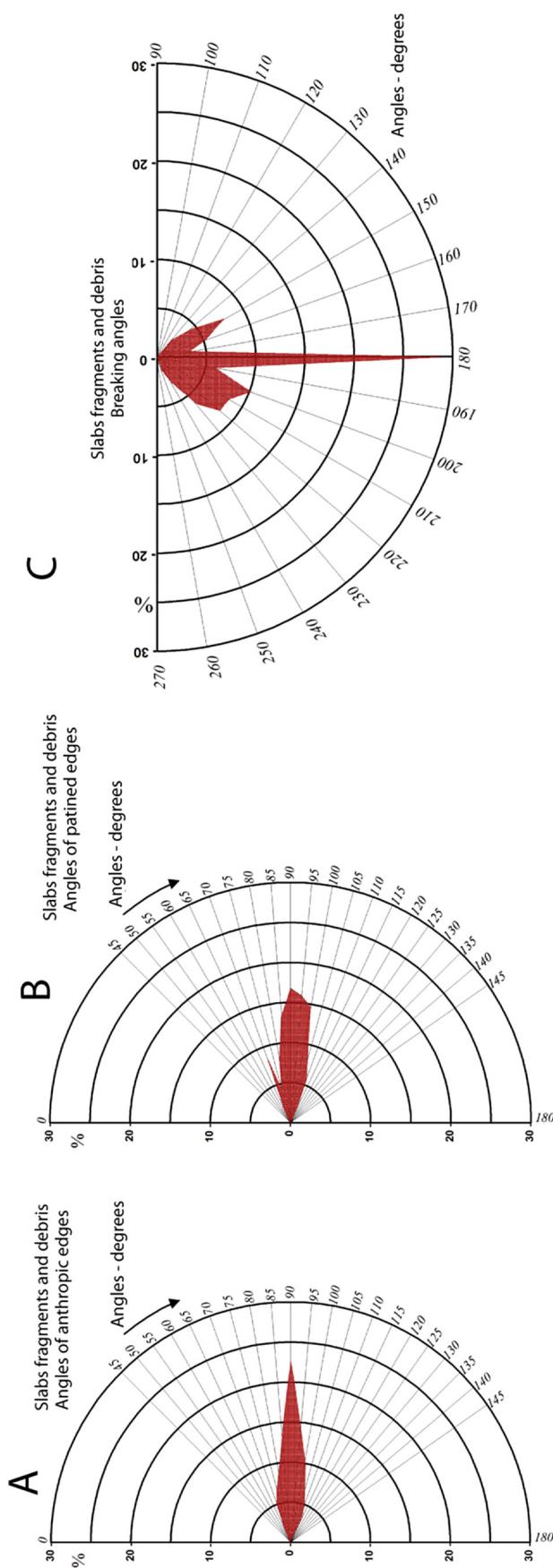


Fig. 13. Angle of the anthropic edges (A) and patinated edges (B) in relation to the natural struck surface and breakage angles measured at the impact point (C).

The marks produced by the experiments were similar to those recorded on the slab fragments found at the site: cortex crushing, presence or absence of impacts, ridges and fissures on the edges, orthogonal and similarly-angled fractures (Fig. 17).

Values of experimental angles measured on orthogonal edges (intersection of the cortical surface and fresh slab edges) may be classified in two groups. The first one is between 85° and 95° (48%). The second one is between 105° and 110° (32%). These values are superior to the angles taken on the slab fragments found on the excavations. When the slab thickness is less than 7–8 cm, we obtain similar angles for both experimental and archaeological slabs.

Regarding the slab breakage, they are rectilinear with an angle of $170^\circ \leq \alpha \leq 190^\circ$ (43%), or show an internal angle of $<170^\circ$ (36%) or outer angle of $>190^\circ$ (18%). We obtained similar ratio for the rectilinear breakages. Ratios of internal and outer angles on experimental slabs are in contrast reversed compared to the archaeological slabs.

We explain the differences between our experimental results and the archaeological data by 1) our experimental slabs were broken in many more fragments than expected disturbing the results on measurements, 2) we may assume that some slabs were shaped or brought outside the site by hominins and consequently could not be measured.

The rarity or absence of shocks on the rounded end of the used pieces, used as a large hammer, appears to be linked to the presence and thickness of the cortex. When the cortex is thin or used (thickness ≈ 1 mm), a single shock is sufficient to break the slab (Fig. 17, A). With more substantial thicknesses (thicknesses of 4, 5, 6 mm), the crumbly cortex is crushed during the first and second shock (Fig. 17, B, C3), exposing the silicification and resulting in breakage upon the next blow. This led to the production of a considerable quantity of whitish powder from the crushed cortex, but practically no siliceous waste from the two obtained sides. The same cortical powder is visible on the end of the hammer, but few or no shock marks were absorbed by the siliceous cortical layer (Fig. 17, C).

5.2. Fragments of slabs with removals

Intentional removals have been observed on cortical surfaces and edges of large slabs found at the excavations (Moncel et al., in press). Angles between the cortical surfaces and the edges are favourable for producing both series of flakes on the edges and cortical flakes on the surfaces.

In order to reproduce that, experiments have been applied on both the cortical surfaces and freshly broken edges of slabs. The choice of the hammer for these experiments has been guided by the presence on the excavations of blocks of hard Jurassic silicifications, hard because lateritized. These blocks of an average weight of 1200 g show an elongated parallelepipedic form ($150 \times 100 \times 50$ mm), easy to hold in hand. The block extremity, used for percussion, has generally a prismatic section. The smooth ridges (3 à 5 mm) allow a good touch on the striking platform (Fig. 18).

Flakes coming from the plane cortical surfaces are wide, with a thick butt and a triangular cross-section. The striking platform of flakes produced on the slab edges is the cortical slab surface (Fig. 19).

We have previously explained the role of the cortex thickness of the slab which could have absorbed the impact of the hammer. During experiments, a hammer of Jurassic silicification was used on cortex of 3–5 cm thick. After percussion, the cortex was completely crushed on its whole thickness. Series of flakes is produced without accident. On each flake, the cortical platform is crushed. The bulb is flat and knapping ripples are regular (Fig. 19, A, C). Flakes are short or long, and 12–15 mm thick. This experimental debitage allows us to reproduce cores found on the excavations (Moncel et al., in press).

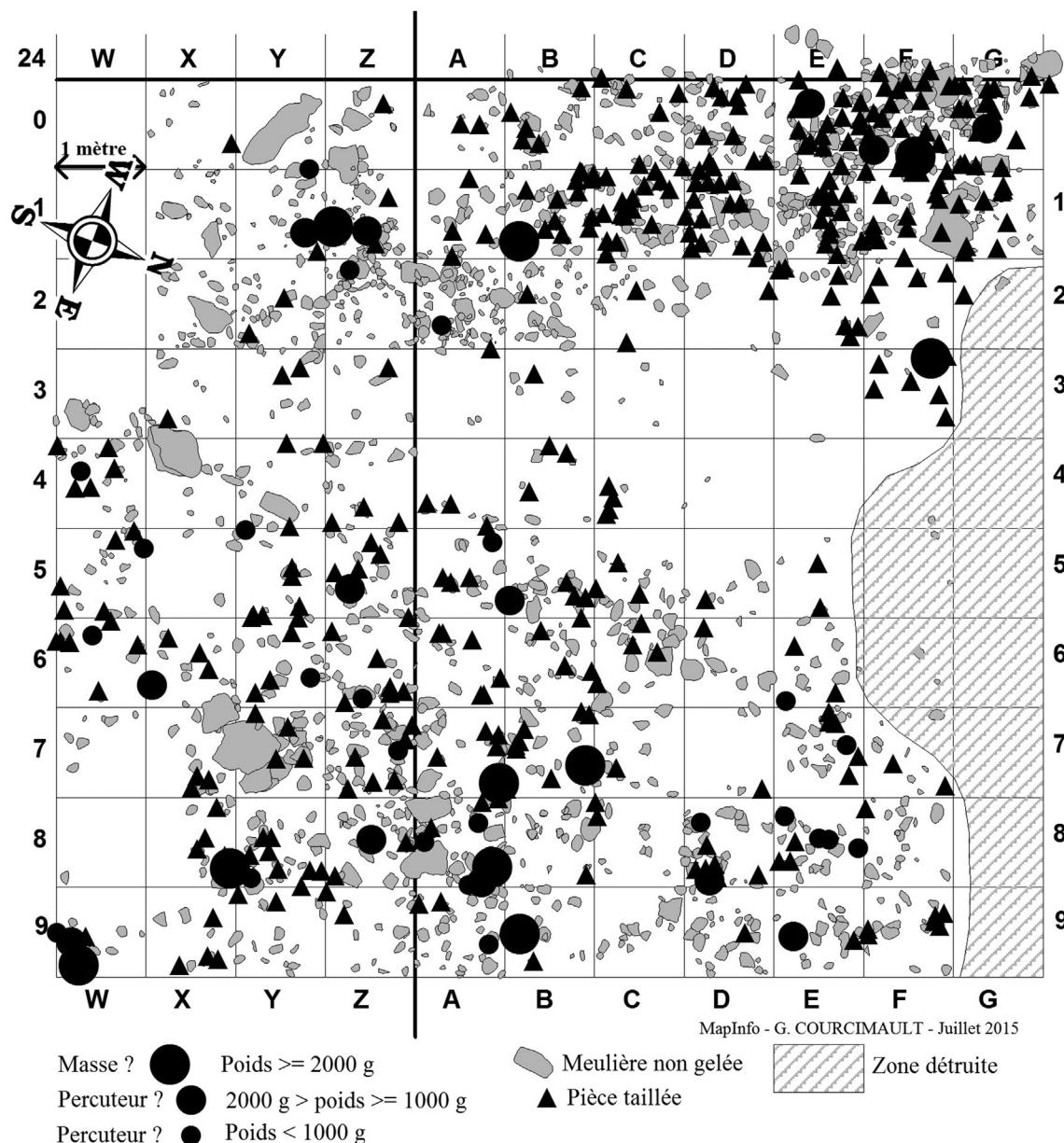


Fig. 14. Distribution of the non-frost-fractured slabs, plates and slab fragments, hammers and flaked and shaped pieces.



Fig. 15. Photograph of the end of the granite hammers (A), quartz (B), Jurassic chert and lateritised quartz showing possible use marks.

6. Discussion

The metamorphic, magmatic and sedimentary rocks forming the accumulations at la Noira come from spreads deposited on the plateau during the Tertiary and currently conserved on the Cher-Arnon interfluve overlooking the site. The stones and blocks were

moved during the Middle Pleistocene by slope phenomena, which were observed and investigated along 50 km of the left bank of the Cher (Debrand-Passard et al., 1978; Lablanche et al., 1994; Manivet et al., 1994).

Abundant already frost-fractured local lacustrine millstone slabs were deposited on the limestone floor. Some of them could have

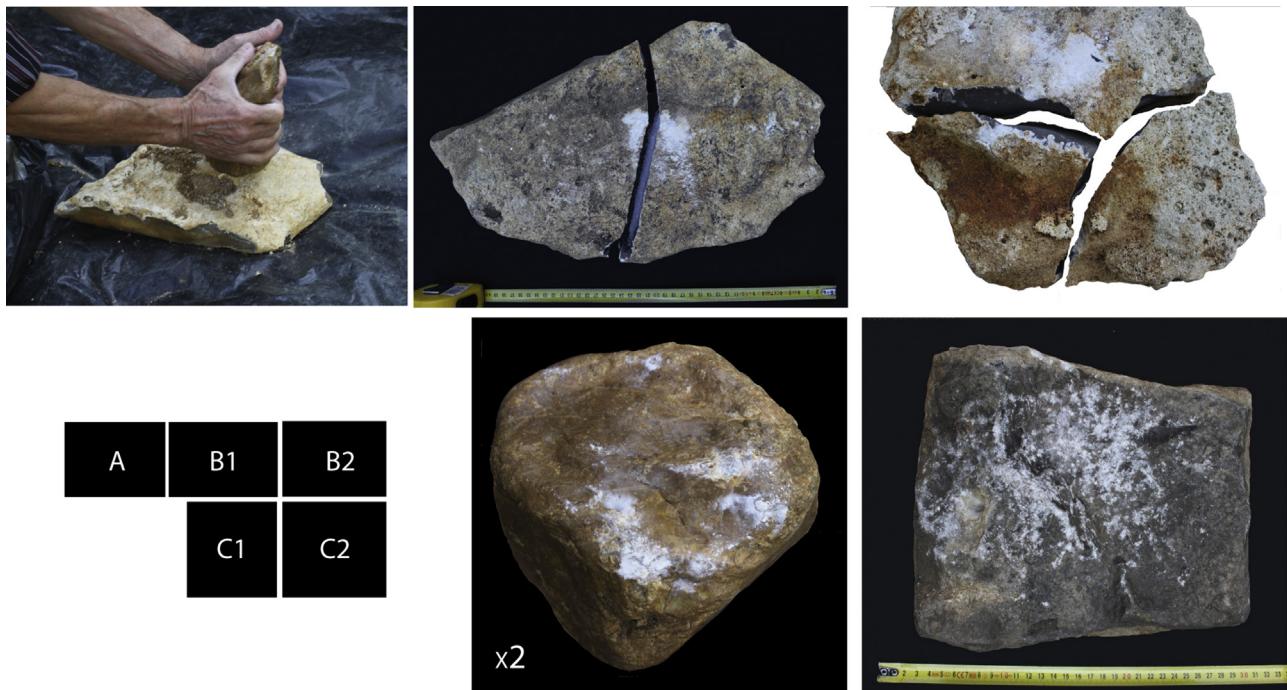


Fig. 16. Experimentation. A. The hammer used to break the millstone slab is a used block of lateritised quartz weighing 3 020 g. B. Crushing of the cortex at the impact point, slab laid on the ground (top) or on an anvil (bottom). C. Marks on the quartz hammer (top) and on the anvil (bottom), partly masked by the siliceous powder derived from the crushing of the cortex (photos J. Courcimault).

been frost-fractured after their deposition; the proportion of these in observed periglacial figures is 79%. In the excavated zone, they are less abundant (<50%).

The formation of unit a, dated at about 700 ka, occurred at the beginning of the glacial period. Sections several tens of metres long show that the unit was intensely reworked by cryoturbation, thereby hindering the characterization of its original deposition mode. In the excavated zone, the two accumulations observed along the west section present a similar layout to that observed at

the lower end of the debris flows (Cojan and Renard, 2006). Conversely, the spread of elements on the incision floor does not appear to correspond to a classical phenomenon of gravitational deposition or to introduction by river discharge, which would have required a torrential competency and would have left visible marks.

Does this spread present evidence of human intervention? Note that frost-fractured and non-frost-fractured slabs were dispersed in identical proportions. Only the non-frost-shattered slabs were used

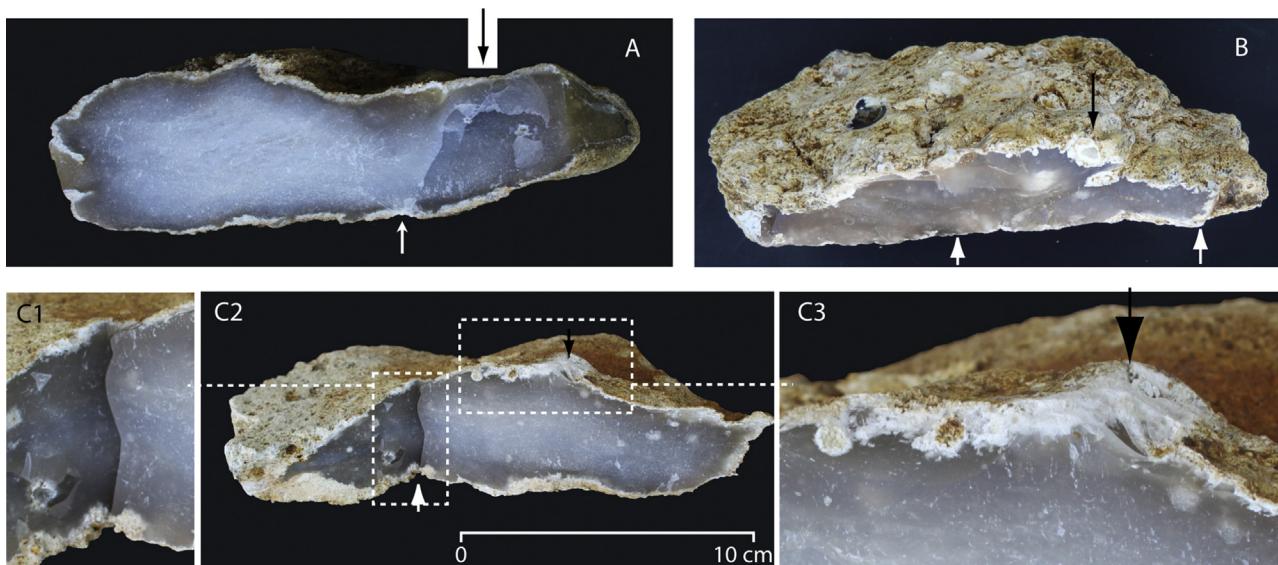


Fig. 17. Fragments of experimental broken slabs with orthogonal edges with an outer (A), flat (B), or internal (C) angle (photos J. Despriée). The black arrows indicate the location of the shocks and crushing of the cortical surface (C3). The white arrows indicate the opposite shocks. The opposite shocks give a ridge (C1) and scars. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



Fig. 18. Jurassic silicification used for experiments of debitage from slab cortical surfaces and from slab fresh edges. Resulting stigmata are less invasive (some scars and crushing). Experiments allow establishing the use as hammers of this type of piece present on the excavations.

as raw materials by hominins and they were gathered on site. Clusters of elements of different sizes, associating slabs, slab fragments and debris with hammers seems to confirm this hypothesis. The absence of debris or fragments resulting from visible breakages on slab perimeters implies that they were deliberately moved to another workshop area beyond the excavation zone (or destroyed during extraction work). Does this zone thus represent preliminary sorting before shaping or knapping?

Elements derived from broken slabs form a homogeneous population of fragments with the following average dimensions: $L = 143$ mm, $W = 106$ mm and $H = 51$ mm. The two dominant modules are wide fragments ($1 < L/W \leq 1.49$: %) and relatively wide fragments ($1.5 < L/W \leq 2$: %). Around the site, in the quarries of lacustrine limestone, entire multi-decimetre slabs can be found in quantity with average sizes of 500/400 mm long and 300/200 mm width. These are not present on the excavations, where the larger anthropic slabs (3%) only measures 250 to 200 mm long and 200 mm width. They may correspond to natural slabs broken in two parts by hominins. Moreover, big slabs with patinated edges are numerous on the slopes and absent on the excavations as well. We found only large frozen slabs, unused by hominins.

All the other anthropic slab fragments form a homogeneous population of 143 mm long, 106 mm wide and 51 mm thick in average. Several phases of breakage are likely at the origin of two modules, large fragments with a ratio length/width between 1 and 1.49 and fragments with a ratio of length/width between 1.5 and 2.

We can also propose the hypothesis that these slabs and fragments with standard modules, representing most of the useable materials found in both accumulations, could have been grouped together. The absence – at the current stage of the study – of “associations” of diverse slab fragments and debris tends to back up this hypothesis. Let us recall that 84.8% of these elements have

sufficiently large dimensions to be used as potential supports for shaping the worked pieces recorded at the site. And that 294 fragments, or 79.5%, present sufficient surfaces and lengths for the shaping of bifaces with average dimensions of $140 \times 90 \times 35$ mm.

The preliminary experiments attest that knapping of millstone flakes may be made from slab edges and cortical surfaces. That is in agreement with what we observe on the excavations on slabs with some removals and cores. Other experiments are ongoing to determine which types of slab (shape and thickness) were preferred for the manufacture of bifaces and other large tools. When possible, bifacial tools indicate that the selected slabs were thin, possibly of almond form that we can consider as a kind of preform. Others were made on fragments of slab and punctually large flakes.

7. Conclusion

This study concerns featureless material. In this case, they are slabs, broken slabs and hammers which could be naturally arrived on the site. It seems to us essential to well describe these pieces recovered on the excavations and understand their presence, meaning and role in hominin activities. In this kind of open air sites, these types of material may be neglected and this makes us ignore some aspects of the hominin behaviours. Experiments allow comparing the whole natural stigmata and the stigmata due to hominins. Both study of this material and associated experiments allow us highlighting some technical behaviours and the first phases of the processing systems performed on the site. At the beginning of the Middle Pleistocene, in the site of la Noira, hominins mainly used a siliceous raw material present on site; millstone formed by diagenesis in Paleogene lacustrine limestone deposits, available as slabs ranging in size from several centimetres to up to a metre. They were taken from accumulations made up of a mixture of endogenous blocks and stones and sedimentary rocks, often unsuitable for knapping.

As frost-fractured slabs of lacustrine millstone can be identified on the basis of the presence of fissures or the specific sound produced by a blow, hominins selected intact slabs of variable quality. These slabs are either whole or totally cortical, or present patinated sides, implying that they were broken naturally at an earlier stage. A certain number of them were found, indicating that they may have been sorted in view of future use. After provisioning, the largest of the slabs were broken, as shown by the fragments and debris with a perimeter limited by one or several non-patinated orthogonal sides. These pieces do not bear evidence of transport but present impact marks, crushing of the cortex with impacts, satellite removals and fissures. These marks were reproduced by experimentation and indicate that breakage results from anthropogenic action. The absence of patina on these breaks shows that

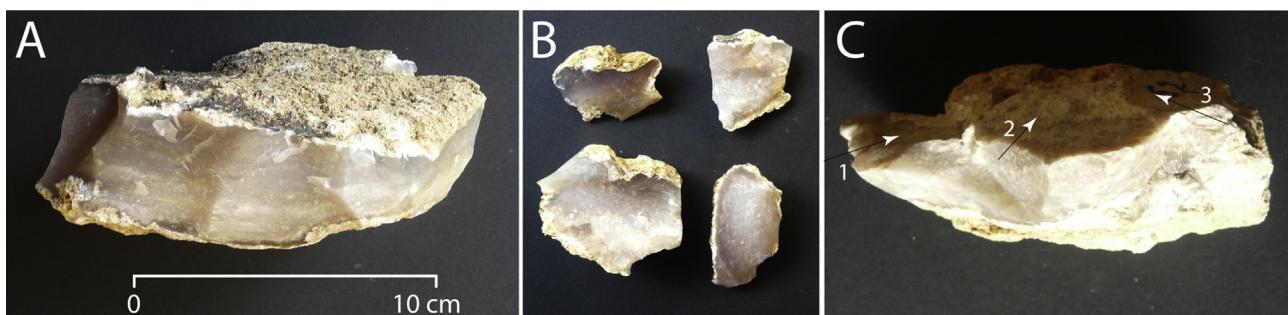


Fig. 19. Experimental attempts of debitage of millstone slabs. First cortical removals and orthogonal removals on the cores discovered on the excavations. The white arrows indicate the second series of removals on the slab surface. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

they occurred after the slabs were introduced to the site. The size of the fragments obtained corresponds to the dimensions of the artefacts found on site, and particularly to those of bifaces and certain large cores (slab thickness was also a selection criterion). A considerable number of slabs, with removals or peripheral shaping, also present similar dimensions (Moncel et al., 2013).

As shown by the distribution of the flakes, cores and partially or totally bifacial pieces, the accumulations were extensively used, which implies that deliberate or unintentional reworking also occurred in the heaps and the spread.

The lacustrine silicifications, occurring as millstone slabs in the region of Champagne berrichonne south of the Vierzon (near the site), had not, up until now, been listed as a raw material used in the earliest Acheulean sites of France or Europe. As was common at Acheulean sites, the raw materials immediately available on site were used.

In the Centre region, the procurement of better quality rocks, such as Cretaceous flint, in the immediate site environment or further away, only appears at about 500 ka (Despriée et al., 2007, 2009). And the same pattern seems to be applicable to Mediterranean regions (Barsky et al., 2013).

Hominins at le Noira, at 700 ka, were able to manage the millstone slabs, selected the more suitable for flaking or shaping, attesting capability to estimate the best stones. Appropriate techniques were used to break these slabs in order to get smaller fragments. The systematic study of all the materials enabled us to advance hypotheses on the behaviour at the site: sorting of raw materials affected by frost, cursory peripheral knapping of slabs of up to a metre long with hammers weighing several kilogrammes, breaking up of large slabs over 10 cm long, displacement of the fragments. This attests the high complexity of hominin behaviour for the management and exploitation of raw material deposits at 700 ka.

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