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Neanderthals and volcanic rocks. Opportunistic behaviour or optimized management?

Les Néanderthaliens et les roches volcaniques. Opportunisme ou gestion optimisée ?

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ABSTRACT

The use of volcanic rocks by Neanderthals is frequently considered to be opportunistic, especially when good-quality stones were rare in the site neighbourhood. An analysis of the lithic series made of volcanic rocks discovered in the Middle Palaeolithic sites of Payre and Sainte-Anne I, located in the south part and at the southeastern margin of the Massif Central of France and dated back to MIS 7 up until the end of MIS 5, illustrates the capacity of Neanderthals to manage these raw materials and enables us to compare the strategies used in two different mineral environments. Shaping and flaking reduction sequences coexist in both sites in varying proportions, depending on the available rocks in the surroundings. At Payre, artefacts made of volcanic rocks are rarer in surroundings rich in flint while at Sainte-Anne I, the different series comprise a large quantity of artefacts made of different basalts and trachy-phonolites in an environment relatively poor in flint. Most of the reduction processes took place *in situ*. Activities outside the sites only appear to have concerned the shaping of some heavy-duty tools and some large flakes. It is likely that volcanic rocks were considered by Neanderthals as a geo-resource, either major or lesser in importance, to provide large flakes and both heavy-duty and light-duty tools, besides flint quartz and other rocks.

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RÉSUMÉ

L'usage de roches volcaniques par les Néanderthaliens est parfois considéré comme la preuve d'un comportement opportuniste, faute de matériaux de qualité disponibles aux abords des sites. L'étude du matériel lithique en roches volcaniques des sites du Paléolithique moyen de Payre et de Sainte-Anne I, localisés dans le Sud et à la marge sud-est du Massif central français et datés des MIS 7 à 5 final, illustre la capacité des Néandertaliens à gérer ces matériaux dans des environnements sensiblement différents. Des chaînes opératoires de façonnage et de débitage appliquées à ces roches coexistent dans les deux

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sites dans des proportions variables, en fonction des caractéristiques de leur mise à disposition dans l'environnement immédiat. À Payre, les objets en roches volcaniques sont minoritaires dans un environnement riche en silex. À Sainte-Anne I, les séries comprennent, à l'inverse, une forte composante locale de roches volcaniques (différents basaltes et trachy-phonolites), dans un environnement relativement pauvre en silex. La plupart des séquences mises en œuvre sur ces matières premières locales se sont déroulées *in situ*. La production à l'extérieur des sites a, semble-t-il, concerné exclusivement certains outils lourds et quelques grands éclats. Il est donc patent que les roches volcaniques ont été considérées par les Néanderthaliens comme des matériaux, tantôt complémentaires, tantôt principaux, susceptibles de fournir à la fois de grands éclats et des outils lourds ou légers, au même titre que le silex ou d'autres matières.

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1. Introduction

Volcanic rocks, as well as quartz, quartzite, limestone or other crystalline rocks, are considered to have been used by Neanderthals when flint was absent or not available in sufficient quantities in the surroundings (*i.e.* Delagnes et al., 2007; Geneste and Turq, 1997; Jaubert, 2001; Moncel et al., 2008; Meignen et al., 2009).

Two early middle Palaeolithic sites located in southeast France, one along the Rhône Valley and one in a mid-mountain context, demonstrate that the relationships between Neanderthals and volcanic stones were complex. The two sites, Payre and Sainte-Anne I (MIS 8–5), are located in two different mineral contexts. The environment of Payre was already a plateau rich in flint on the right side of the Rhone Valley, while the surroundings of Sainte-Anne I, within the Massif Central middle mountains, was at the time relatively poor in flint but rich in volcanic rocks. Despite these two different geological settings, volcanic rocks were used at both sites.

In European Palaeolithic contexts, the use of volcanic rocks generally occupied a peripheral role, whereas in Africa, dolerite, obsidian and different other lavas were intensively used over time for flaking and shaping pebble-tools and/or flake-tools, and for percussion (Braun et al., 2008, Delagnes and Roche, 2005; Gallotti et al., 2010; Harmand, 2009; Mora and Torre de la, 2005). In the Middle East, volcanic rocks were generally used more sporadically and depended strongly on the geological features of the surroundings (for instance, the early site of Dmanissi, the Acheulean sites of Kundaro and Tsona, Gesher Benot Ya'akov in the Levant) (Rodafnidia-Lisvori) (Biglari and Shidrang, 2006; Galanidou et al., 2013; Goren-Inbar et al., 2015; Mgeladze and Moncel, 2016; Mgeladze et al., 2011; Slimak et al., 2008; Wilson, 1988).

The technological analysis of volcanic rock series is frequently problematic because it is difficult to recognize and describe the knapping stigmata such as the bulb, impact points and technical features of the removals. As well as quartz, the volcanic stones do not react like flint (see Geneste and Turq, 1997). Moreover, the degree of blunting and/or alteration at Payre is often high and causes total or partial illegibility of the superficial surfaces of some objects. At Sainte-Anne I, the objects are often fractured (knapping fractures and post-depositional events); some were blunted, depending on their location in the cave and material loss occurs on the edges and the surfaces. Despite the fact that volcanic stones do not always offer good observation conditions, detailed analyses were conducted for the industries from the different units of both sites.

This study focuses on the technical strategies applied to basalts at Payre and basalts and trachy-phonolites at Sainte-Anne I and our final goal is to discuss the role of the volcanic rocks in Neanderthal lithic series compared to the other raw materials. Whether opportunistic or optimized, these strategies could point to a possible complementary management of diverse lithic resources, controlled by geological occurrences, functional needs, technical and/or cultural traditions.

2. Materials and methods

2.1. Methodology

The lithic assemblages were studied by using the concept of *chaîne opératoire* applied to each major class of raw material. The origin and the petrographic characters of the raw materials, including the volcanic rocks, were studied by field geological surveys, by macroscopic and microscopic analysis for the Sainte-Anne I site and macroscopic analysis for the Payre site (Fernandes et al., 2008).

The technical processes we studied following the classical literature (Boëda, 1993, 1994; Boëda et al., 1990; Geneste, 1988; Geneste and Turq, 1997). The knapping, shaping and retouching techniques and modes we could identify were recorded according to the technical characteristics of the volcanic rocks and the tool types being manufactured. The analyses of the complete operative scheme was conducted according to the various techno-economic phases that underline the human strategies for managing their environmental resources (*i.e.* Boëda, 1993, 1994; Boëda et al., 1990; Geneste and Jaubert, 1999; Mourre, 1996, 1997).

Data are presented according to large technological categories of pieces and the specific features of each site. For Payre, we first present the category of whole pebbles, which totals a high quantity of pieces, then the heavy-duty component and the flakes resulting from flaking or shaping. For Sainte-Anne I, data are distinguished by the type of volcanic stones (basalt and trachy-phonolites) and introduced through the core technologies and the shaping processes, including for each the end-products.

2.2. The lithic series and their components

The site of Payre is located on a promontory along the Rhône Valley; it was first a cave and then a rock-shelter (Fig. 1). It was excavated between 1990 and 2002 and yielded a sedimentary sequence more than 5 m thick with eight occupation units dated from MIS 8–7 from four units (unit G [units Gb, Ga], unit F [units Fd, Fc, Fb, Fa, and unit E], and the end of MIS 6/beginning of MIS 5 [unit D]) (Moncel, 2008a, b; Moncel et al., 2008; Valladas et al., 2008). Fourteen human remains were found, nine of which were in unit G (Condemi et al., 2010; Moncel et al., 2008).

Basalts total 4 to 9% of the series from each occupation phase, which is slightly more than quartzite (0.5 to 1%), quartz (2 to 8%) and limestone (1%). These stones are available near the site, along the banks of the Rhône and in the Payre River, at the foot of the site. Basalts are from the Coirons basaltic plateau upstream of the Payre River, to the west of the site. Flint is the main raw material over time (80 to 92%) (Fernandes et al., 2008), collected on the southern plateaus on the right side of the Rhône, on outcrops located between 5 and 15–30 km from the site. The Barremian–Bedoulian flint was the main type, gathered as fragments of nodules or large flakes, secondarily as conglomerate pebbles. Some flakes from long-distance outcrops were collected 60 km south of the site. Neanderthals moved along south-north routes, although the south provides the largest number of flint sources of varying quality.

Sainte-Anne I was re-excavated from 2006 to 2015 and the sequence observed at the front of the cavity in the sector of the current porch and the palaeo-porch, revealed three archaeostratigraphical units (named from top to bottom J0–J1, J2, J3) separated by scree units (E1–E2–E3). (Raynal and Bertran, 2007) Inside the cavity, large rock collapses are less abundant. In some of the excavated zones, frost action reorganized the original disposition of artefacts. The site is dated to MIS 6/5e (130–80 ka) by ESR dating on tooth enamel and OSL dating on sediments.

The raw materials study indicates the preponderance of local basalts and trachy-phonolites (Kieffer and Raynal, 2007) (60%) and quartz (20%), associated with 26 different types of flint (20%) from local and regional sources (Fernandes, 2012; Fernandes and Raynal, 2007, Fernandes et al., 2006, 2008). Volcanic rocks were gathered from colluviums, fossil alluviums and active river beds within a radius of 5 kilometres. All flint sources located in the close environment and the regional sphere (up to 32–46 km) were more or less regularly used and some exogenous flints are present.

3. Results

3.1. Technological aspects of the basalt use at Payre

3.1.1. Whole pebbles

Whole basalt pebbles dominate the series in each unit (Table 1; Fig. 2). Pebble morphology in unit Gb suggests a selection according to the type of management. The whole pebbles are mainly ovoid, between 50 and 140 mm long, while the broken pebbles are more quadrangular or ovoid in shape. The latter are larger, from 70 to 200 mm long and are broken by simple or multiple fractures.

Table 1
Number and types of basalt artefacts according to the units, from the base (unit Gb) to the top of the sequence (unit D) in Payre.
Tableau 1
Nombre et types d'objets en basalte selon les unités, à partir de la base (niveau Gb) jusqu'au sommet de la séquence (unité D) dans Payre.

Technological category	J1 (Nb)	J2 (Nb)
Natural objects	**146**	**175**
Acquisition	**42**	**34**
Initialization		
First flake	11	
Primary flake (75%)	80	88
Flake (50%–25%)	195	292
Production		
Shaping out		
Levallois	81	91
Discoïde	75	130
Undifferentiated	16	17
Shaping	149	249
Débitage/façonnage		
Discoïde	209	333
Levallois	71	68
Others	10	19
Undifferentiated flake	534	1106
Shaping	35	
Utilisation		
Heavy-duty tool	30	10
Retouched flake	162	182
Tool fragment	36	6
Abandonment (core)		
Levallois	6	13
Discoid	18	15
Others	9	5
Undifferentiated	33	26
Undifferentiated products	174	119

In unit Ga, most of the whole pebbles measure between 30 and 90 mm, while some large pieces measure from 150 to 300 mm. In most cases, weight is less than 500 g, except for the largest pebbles which weigh between 5 and 11 kg. They are frequently round or oval. Despite superficial surface alteration, 14 pebbles bear well-defined active percussion marks.

In unit D, the abundant whole pebbles can be divided into three groups: 1) 40–130 mm (the largest group), 2) 130–200 mm and 3) 250–300 mm. They are flat, oval or quadrangular and thick (from 20 to 50 mm). They generally weigh less than 1 kg, but a few pieces weigh 10 kg. Some pebbles have crushing marks, small fractures (persistent shocks) or pellicular scars, mainly on the angles, and ridges or the narrowest ends. Location of these stigmata and experimentation suggest that these pebbles could be used as active hammers. Some of the largest pebbles bear marks on one surface and experimentation and ethnographical observations indicate that very large pebbles can be used both as active and passive hammers.

3.1.2. Flaking or shaping?

Pieces with several removals may be classified as cores, chopper-cores or pebble-tools and successive processes can occur on a same piece over time (Tables 1–2). These

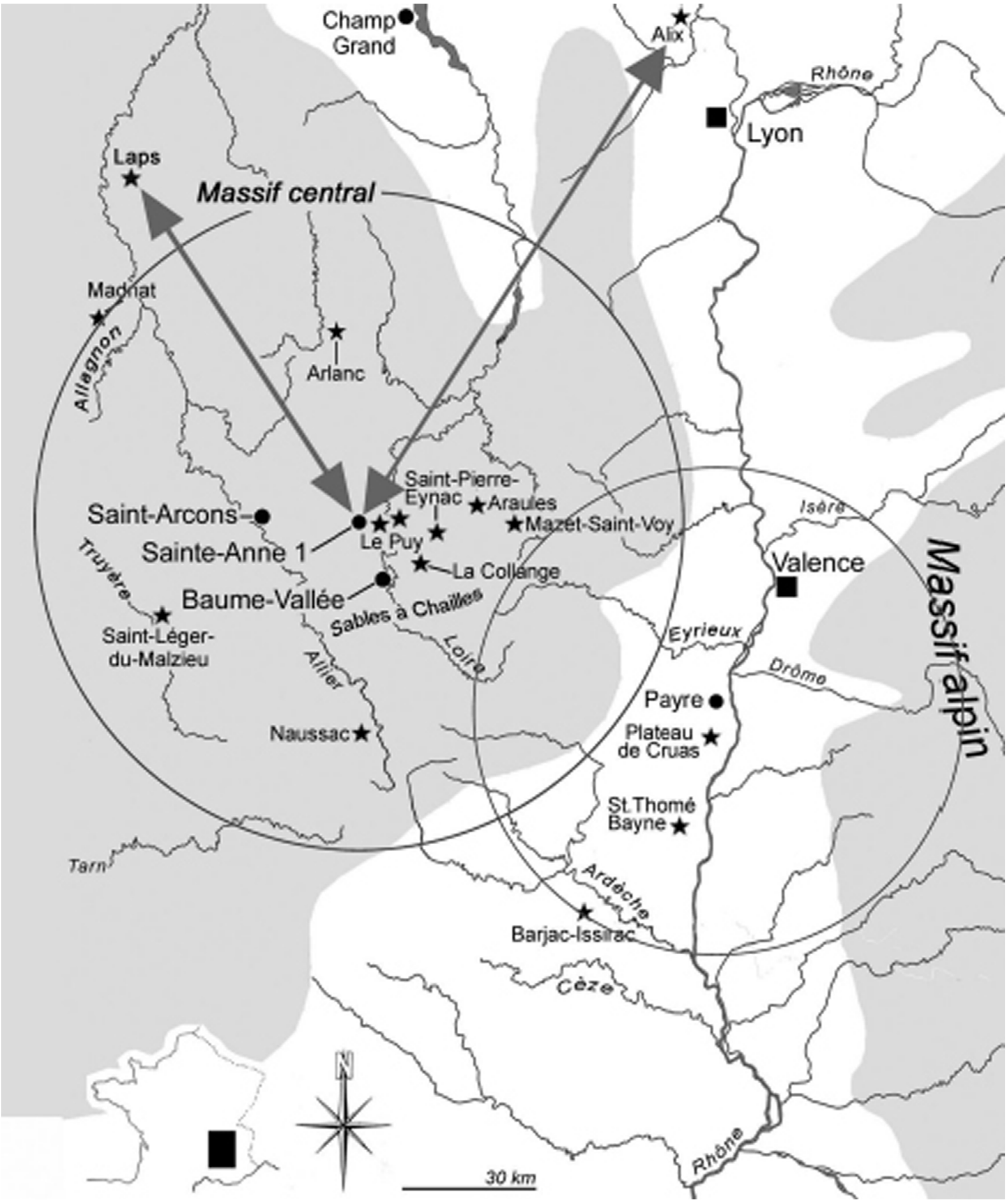

Fig. 1. Location of Payre and Sainte-Anne I. Black dots indicate the archaeological sites and stars point to the flint sources. Arrows indicate the distances from the site to the outcrops (after Fernandes et al., 2008, p. 2366).

Fig. 1. Localisation des sites de de Payre et de Sainte-Anne I. Les ronds noirs indiquent les sites archéologiques, les étoiles les gîtes à silex, les flèches, les distances à parcourir (d'après Fernandes et al., 2008, p. 2366).

pieces retain invasive cortex and bear a small number of removals. The latter are flat, invasive or marginal (Fig. 3.6). Polyhedral pieces characterize unit Ga. They bear convergent and invasive removals, occasionally hinged and localised on one side. They are produced by irregular rotation. Sometimes, the surface and a pebble back are shaped by small flakes (Fig. 3.7). A carinated end-scraper was shaped on a large cortical flake by several bipolar and invasive removals.

In unit F, some large pebbles were partially or totally shaped on two surfaces by abrupt removals. Even if we take into account the angle of the cutting edges, of the striking platform and the organisation of the removals, it remains difficult to identify the shaping or flaking

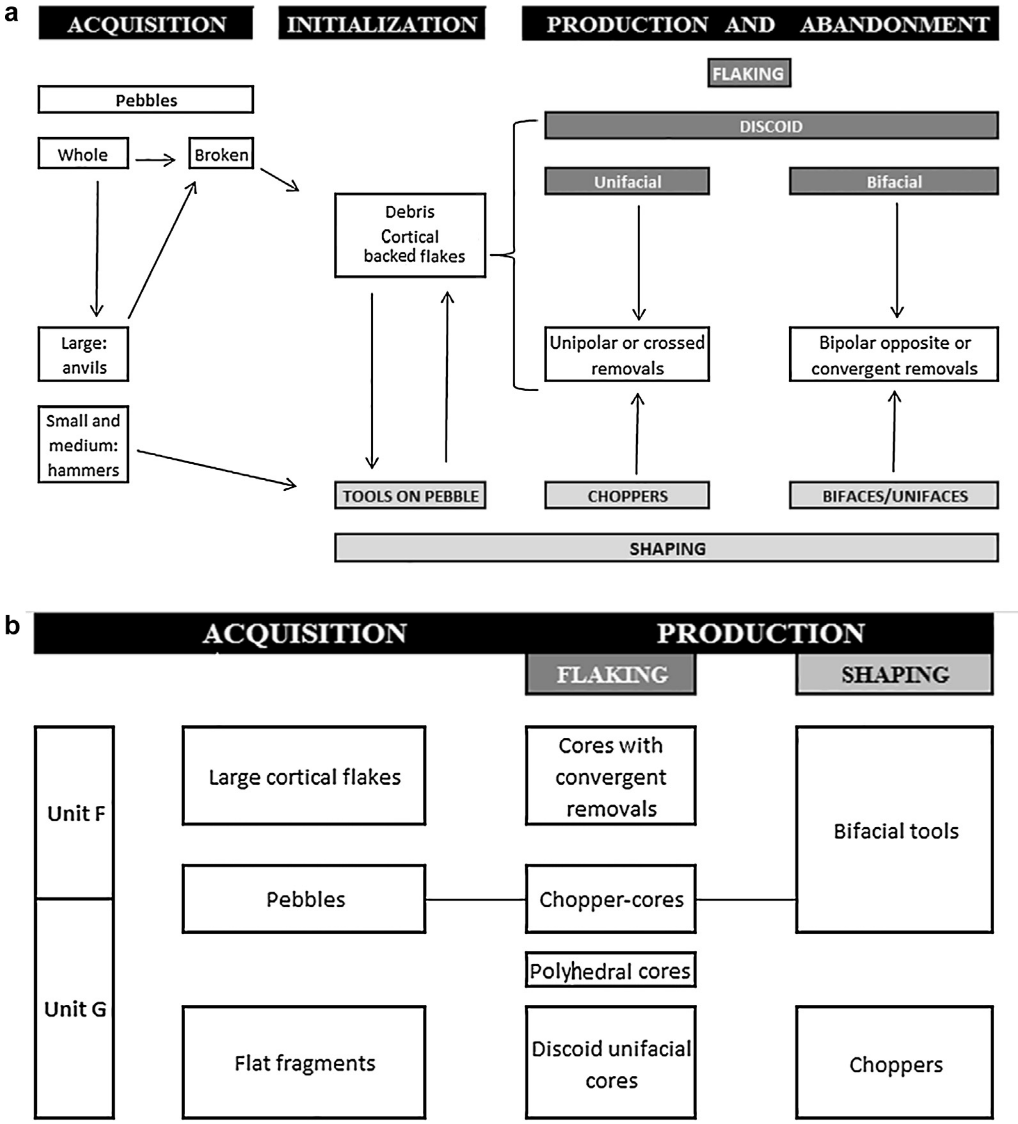

Fig. 2. Schemas of the main reduction sequences applied to volcanic rocks in the units D (a) and F and G (b) of Payre.

Fig. 2. Schémas des principales chaînes opératoires appliquées aux roches volcaniques dans les unités de Payre : (a) unité D ; (b) unités F et G.

processes. Some pebbles were partially reduced by bipolar, crossed or unipolar removals. The localisation of the cortex and the organisation of the removals (centripetal or bipolar scars) on the small by-products (flakes) indicate that pebble management probably occurred progressively and laterally (50% of backed flakes) from various striking platforms (flaking reduction sequence or complex shaping). Several exploitation phases are observed. Some series of flat and invasive flakes were followed by marginal abrupt flakes for reshaping. Management of rectangular blanks (fragments, flat pebbles, large cortical flakes) produced elongated and laminar products.

In unit D, the barely legible pieces with removals are 70–90 mm long and 40–50 mm thick. Among them, we may mention a flake exploited by bipolar removals (probable Kombewa core), some pieces with convergent removals on one surface and some other totally exploited pieces badly preserved.

3.1.3. *Shaping and heavy-duty tools*

Evidence of clear shaping is attested while a few small flakes are retouched (Tables 1–2).

Shaping is attested by pebbles with unifacial removals, or evidence of pebble breakage followed by series of short removals on the longest edge of the pebble. They are considered to be choppers on account of the cutting edge angle.

Unifacial tools are present in units E and D. A flake cleaver on a badly preserved flake with centripetal removals is noted in unit D (Fig. 4.3). The morphology of the blank is sometimes preserved with a back opposed to the retouched part.

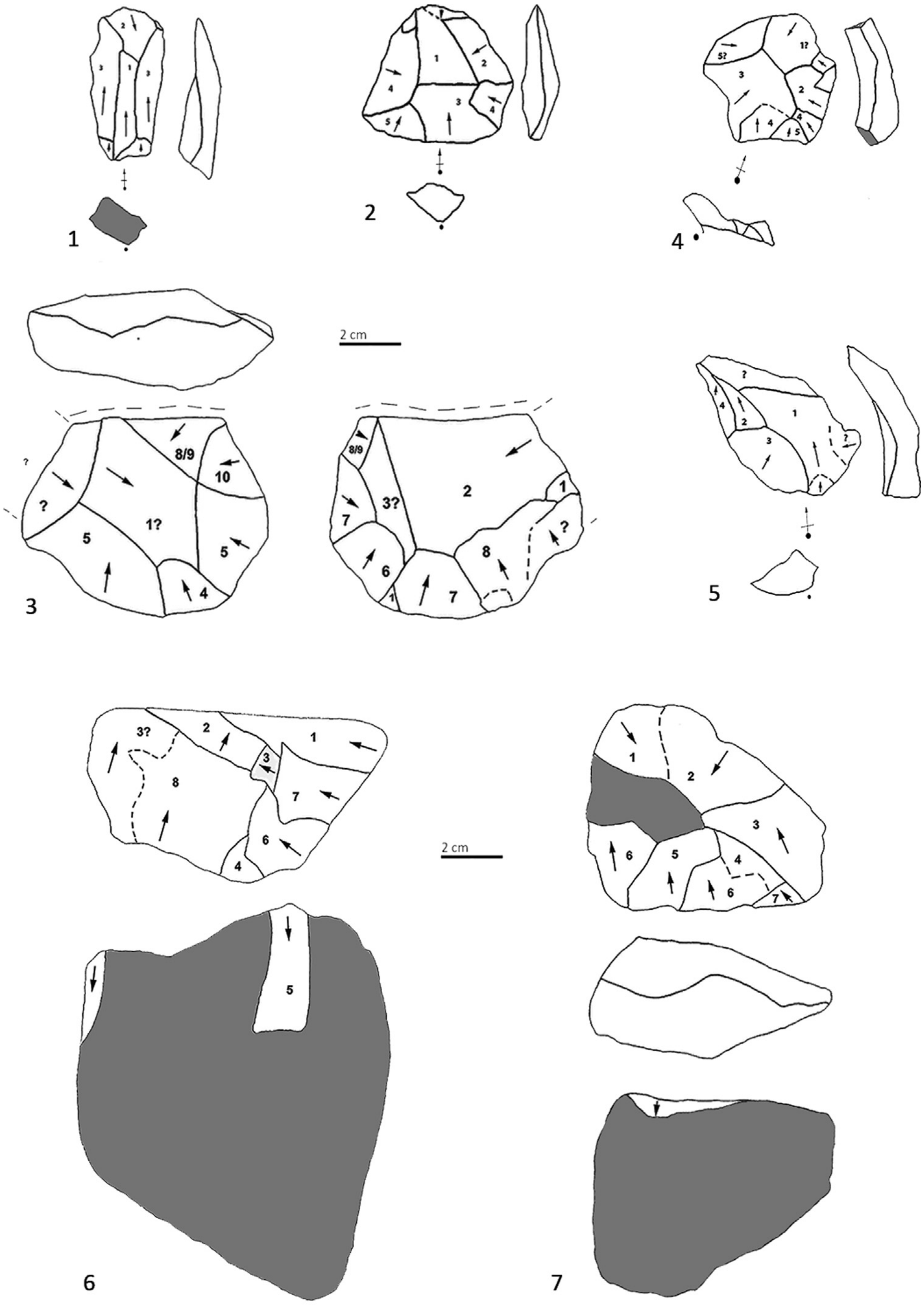

Fig. 3. Basalt objects at Payre. 1–2. Flakes with centripetal or bipolar removals (unit D). 3. Bifacial core (unit D). 4-5. Flakes with centripetal removals (unit Ga). 6. Chopper-core (unit Ga). 7. Unifacial core (unit Ga). (Drawings: C. Santagata).

Fig. 3. Objets en basalte de Payre. 1–2. Éclats avec enlèvements centripètes ou bipolaires (unité D). 3. Ébauche de biface (unité D). 4–5. Éclats avec enlèvements centripètes (niveau Ga). 6. *Chopper-core* (niveau Ga). 7. Nucléus unifacial (niveau Ga). (Dessins : C. Santagata).

The few bifacial crude tools were generally shaped by abrupt invasive hinged and convergent removals respecting the bifacial symmetry (units G and F). Sometimes, they have a partial cortical back or a double point (unit G). The cutting edges were occasionally retouched and intensively crushed (unit F: Fig. 4.1–2).

Considering the handaxes from unit D, the shaped part of the tool is less extended than the cortical preserved area and one surface was often more shaped than the other. A broken point (S fracture) suggests evidence of *in situ* use (unit G) despite lack of micro-wear analysis on this piece.

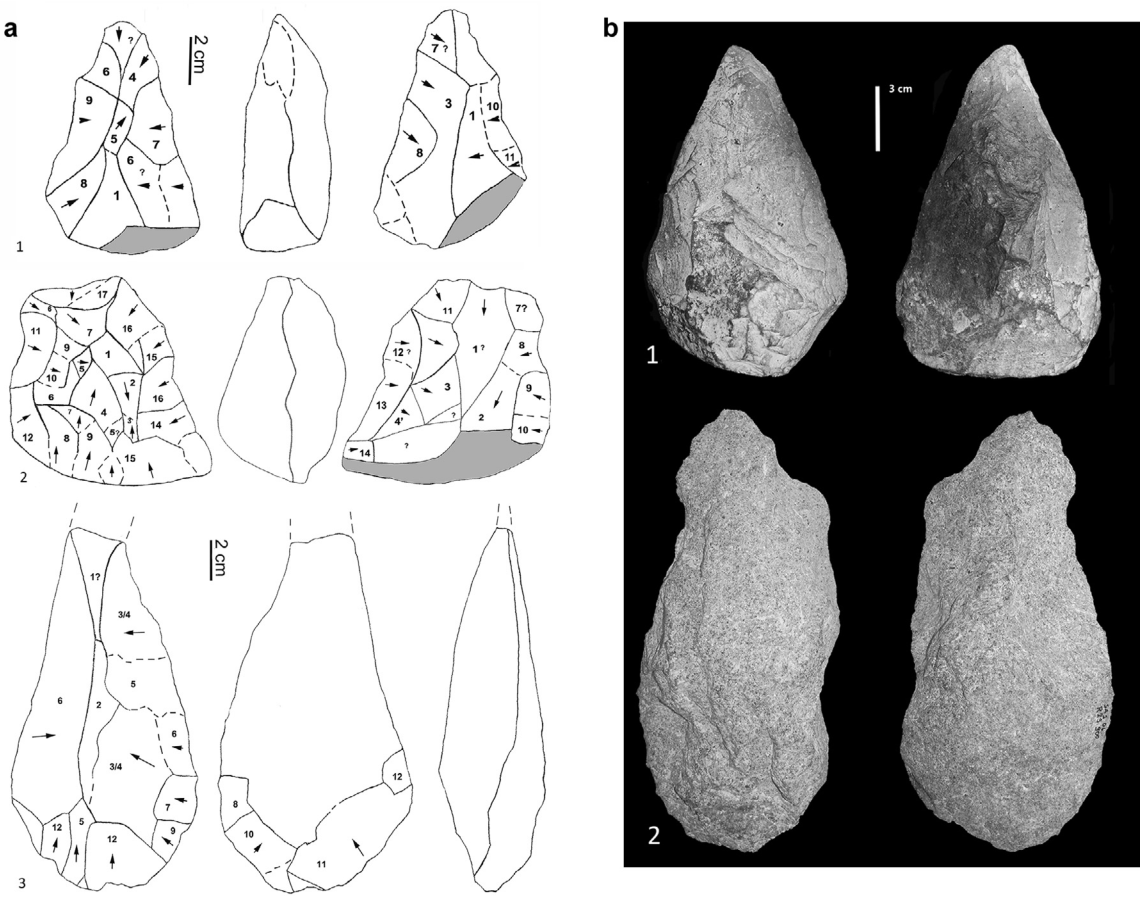

Fig. 4. Volcanic rocks shaping chain a: at Payre. 1–2. Basalt bifacial pieces (unit F). 3. Basalt partial bifacial tool (unit D). (b) At Sainte-Anne I. 1. Basalt biface (unit J1). 2. Trachy-phonolite bifacial tool (unit J1). (Drawings and photo: C. Santagata).

Fig. 4. Chaîne de façonnage en roches volcaniques. (a) Payre. 1–2. Pièces bifaciales en basalte (niveau F). (3) Objet bifacial partiel (niveau D). (b) Sainte-Anne I. 1. Biface en basalte (niveau J1). 2. Objet bifacial en trachy-phonolite (niveau J1). (Dessins et photographie : C. Santagata).

Table 2
Number and technological attribution to determined groups of basalt artefacts from the base (unit G) to the top of the sequence (unit D) at Payre.
Tableau 2
Nombre et attribution technologique à des groupes déterminés d'objets en basalte de la base (unité G) au sommet de la séquence (unité D) à Payre.

	D (Nb)	E (Nb)	F (Nb)	G (Nb)
Acquisition	6	1	7	9
Initialization				
Cortex remains **(100%)**	14	2	15	12
Cortex remains **(> 75%)**	14		10	8
Cortex remains **(> < 50%)**	19	1 (> 50%)	21	12
Cortex remains **(> 25%)**	4		1	4
Production				
Shaping out	14	0	17	8
Flaking/shaping	59	7	66	53
Heavy-duty tool	12	1	4	15
Abandonment	9	1	5	21

3.1.4. Flakes

With the whole pebbles, flakes account for most of the series (Figs. 3, 4). They are generally cortical and can result from pebble percussion actions (Tables 1 and 2). However, some bear scars and could result from the shaping and resharpening of pebble-tools or longer reduction processes aimed at flake production.

Flakes from unit Gb are unretouched and measure between 20–30 and 80 mm. The cortical zones indicate that they were undoubtedly produced by *in situ* shaping. The large cortical flakes are rare and probably imported.

Many flakes from unit Ga are totally cortical, possibly derived from shaping or percussion activities. However, removals on some unretouched flakes indicate that centripetal or bipolar exploitation on pebbles took place, perhaps related to occasional unifacial discoid core technology (Fig. 3.6), as observed on some pieces with invasive cortical zones and a small number of removals (Fig. 3.4–5).

In unit F (units Fd, c, b and a), the basalt was mainly brought to the site as pebbles, except for some large flakes extracted from voluminous pebbles from the bed and the alluviums of the Payre River. These large flakes were kept entire.

Unit D delivered the highest quantity of flakes. It is also the unit with the most abundant volcanic rocks. The technological features of these flakes suggest various production processes. At the beginning of exploitation, some primary flakes were produced from rectangular pebbles and followed a unipolar or bipolar direction. The cortex was eliminated progressively (Fig. 3.1). Then, opportunistic unifacial or bifacial (discoid?) flaking was performed depending on the rock quality. Non-cortical flakes show a straight profile and a plain lateralised butt with no sign of preparation of the striking platform. At the end, the removals were possibly alternately detached in order to keep on flaking as long as possible (Fig. 3.3). Bipolar or convergent removals attest to either flaking or shaping of unifacial or bifacial tools (Fig. 3.2). Conversely, unipolar or crossed removals could be the result of simplest reduction sequences of shaping or flaking processes (choppers or chopper-cores).

3.2. Technological aspects of artefacts made of basalts and trachy-phonolites at Sainte-Anne I

3.2.1. Core technology

Two main core conceptions, discoid and Levallois, were applied to basalts and phonolites in both units (Santagata, 2012; Santagata and Raynal, 2007).

3.2.1.1. The artefacts made of basalts. Discoid conception is predominant.

In unit J2, the technical flaking constraints were managed in accordance with the characteristics of the basalt. Pebbles and blocks were knapped alternately by marginal unipolar removals or by several series of bipolar and crossed removals (Fig. 5.5). Sometimes, percussion on an anvil is attested by double percussion impacts on cores. The resulting flakes are flat, with convergent and unipolar partially overlapping removals (Fig. 5.1–3). They have cortical or unretouched backs. Products from core management and debitage optimal phase were lateralised and participated in maintaining core convexities.

In unit J1, the first phase of flaking was bipolar and convergent. The plain butts of the predetermined products and the cortical back of the predetermining products indicate that there was no core preparation (Fig. 6.2–4). In all cases, the knapper tried to take advantage of the material constraints by using the best percussion angle available or by alternate production on both surfaces.

The second conception is Levallois, mainly recurrent bipolar or preferential.

In unit J2, some Levallois points were detached by bipolar or convergent removals. At least three series of predetermined flakes were produced (Fig. 5.6–8). Each series of removals was separated by a preparation phase of the core surface and sometimes of the core edges (core edge flakes). The cores are exhausted (Fig. 5.9–10).

In unit J1, the degree of exploitation of the Levallois cores is high (Fig. 6.5–6). The flakes bear standardised features and were occasionally lateralised for convexity maintenance. The removals were unipolar or convergent. When knapping started, some flat invasive recurrent centripetal flakes were produced. Convexities were managed by marginal and abrupt flakes, or elongated flakes. The second phase produced a new series of products by recurrent bipolar flaking, rarely by unipolar flaking. At least two phases of debitage optimal phase are visible on some end-products.

3.2.1.2. The artefacts made of phonolite and trachy-phonolite industry. In unit J2, Levallois core conception was mainly applied to phonolite slabs. The first cortical removals attest to adaptation to slab morphology. Flaking took place regularly by invasive unipolar removals, irregular and rapid production of some flakes that contributed to the maintenance of the lateral and distal convexities of the cores during the debitage optimal phase. The rare facetted butts indicate limited preparation of the surfaces. The Levallois debitage optimal phase is visible on flakes with bipolar and convergent removals. Discoid and Levallois conceptions were sometimes employed alternately on a same core, probably to optimize the reduction of the core. Some removals on discoid cores suggest a final preferential Levallois flake.

In unit J1, the phonolite products also indicate Levallois conception, then secondly discoid production. The initialization of the blanks (mainly slabs) took place by standardised flaking and invasive products. The flakes were detached along blank edges. The lack of cortical zones on the proximal part of flakes suggests bifacial core management, which was not very intensive. These flakes are more or less marginal on the surface, perhaps because the slabs were relatively thin. During the debitage optimal phase, flaking followed the length and the width of the slab. For the *Levallois* chain, flakes from the debitage optimal phase were produced by unipolar, bipolar or crossed removals. In the final phase, a preferential flake or some small flakes from the debitage optimal phase were produced. The lithological structure of the raw material forced the core to be irregularly managed during flaking.

3.2.2. Shaping and heavy-duty tools

The heavy-duty component is composed of choppers and handaxes on pebbles, slabs and large flakes. Two or more series of removals were alternately produced on the choppers. Handaxe and uniface shaping did not follow any precise technical choices (Fig. 4b). The technical features were strictly related to blank type and/or the petrography of the raw material. Shaping is invasive, sometimes using at first a fracture to reduce the thickness of the blank Flakes related to shaping are present in small quantities. They do not technically correspond to the characteristics of the scars visible on the handaxes. They show a diffuse bulb, a linear profile and a plain butt and were detached with a very acute angle.

There are a few retouched products, perhaps due to the resistance of the cutting edges of volcanic rock or the poor preservation of the surfaces. In unit J2, few Levallois flakes in basalt were retouched, perhaps due to their morphometric standardization to produce some specific tools: simple or denticulate scrapers, an end-scraper, a cleaver and some choppers and notches (total of 41 tools including one Quina scarper and a majority of scrapers and notches). The cleaver is a large and thick flake with a flat platform and some centripetal removals. Levallois flake-tools in phonolite (notches, scrapers and denticulated scrapers) show a selection of blanks after morphometric criteria (cortical and rectangular flakes among the largest of the series).

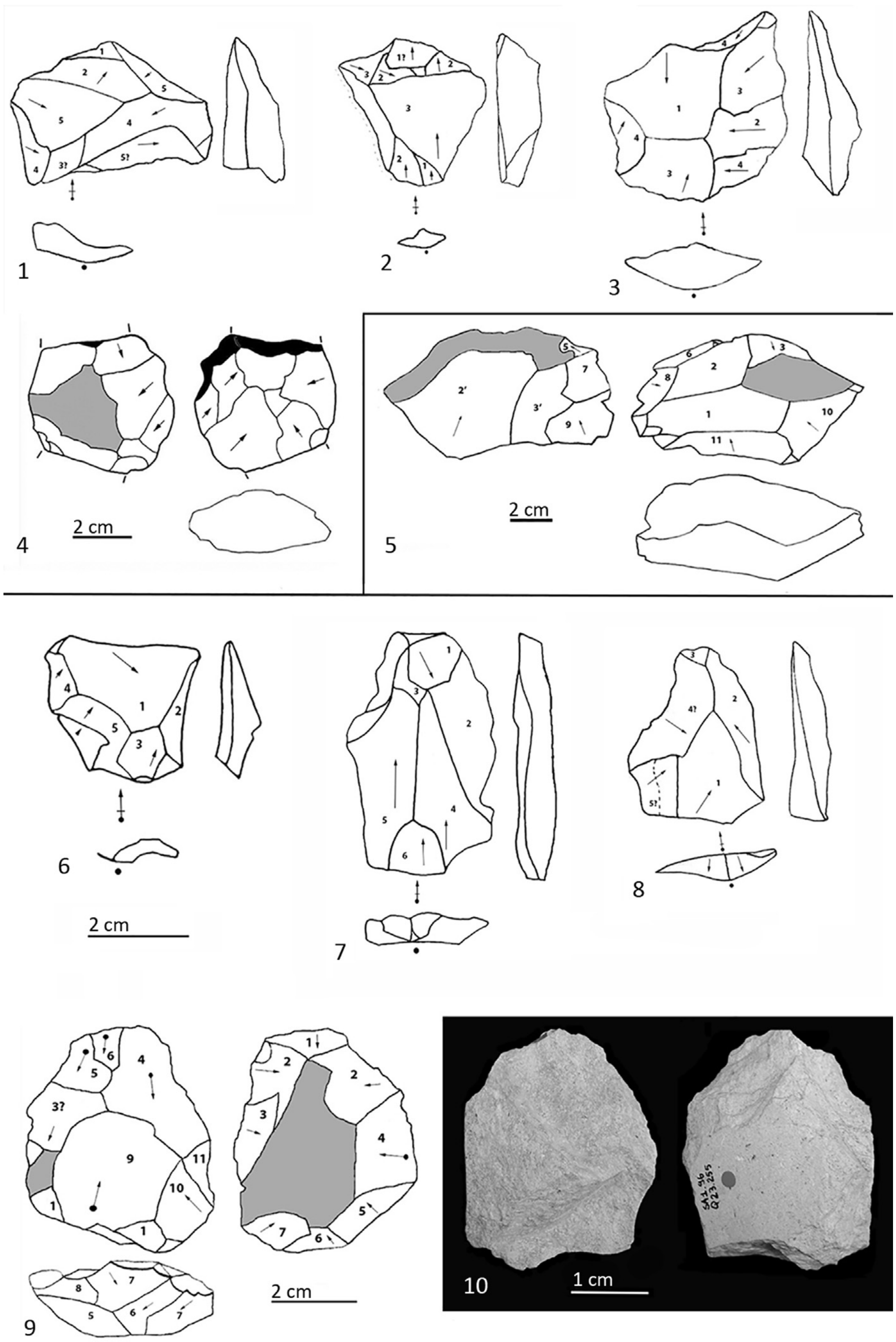

Fig. 5. Basalt pieces from units J2 at Sainte-Anne I. Flakes related to bifacial discoid core technology (1–3) and cores (4–5). 2. Recurrent Levallois flakes (6–8) and cores (9–10). (Drawings: C. Santagata).

Fig. 5. Objets en basalte du niveau J2 de Sainte-Anne I. Éclats de chaîne discoïde bifaciale (1–3) et nucléus (4–5). 2. Éclats Levallois récurrents (6–8) et nucléus (9–10). (Dessins :C. Santagata).

4. Discussion

4.1. Role and management of volcanic rocks during the early middle Palaeolithic

At Payre, objects made of volcanic rock are a minority in an environment rich in flint. These rocks were collected in secondary position in alluviums. The reduction sequences on basalt artefacts are almost complete and mostly related to the shaping of pebbles or big flakes produced out of the site. An evidence of flaking is suggested by the organisation and density of removals on some pieces. Conversely, the Sainte-Anne I series includes a large local component of volcanic rocks (basalts and trachy-phonolites) in an

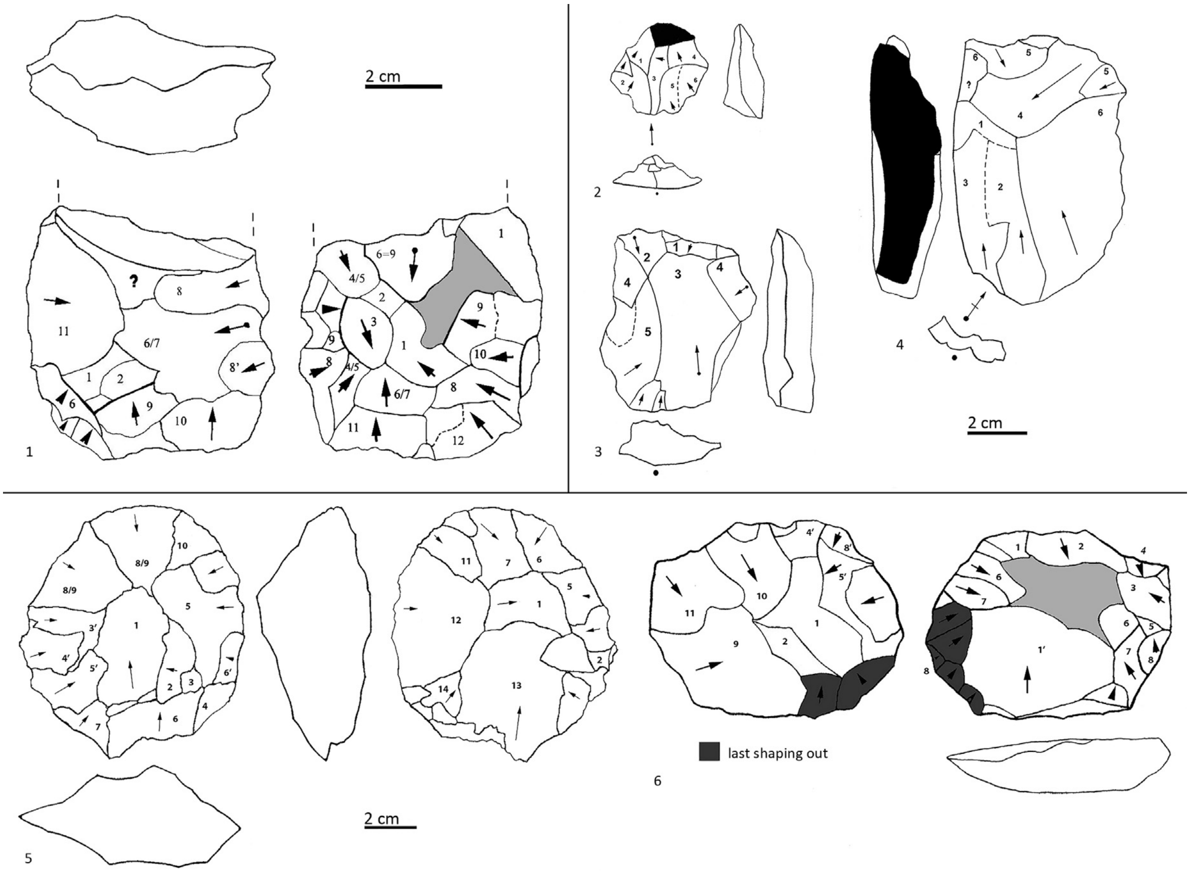

Fig. 6. Basalt discoid and Levallois core technologies in unit J1 at Sainte-Anne I. 1. Bifacial core. 2–4. Optimal debitage phase flakes. 5. Preferential Levallois core. 6. Centripetal Levallois core. (Drawings: C. Santagata).

Fig. 6. Chaînes opératoires discoïdes et Levallois appliquées au basalte dans l'unité J1 de Sainte-Anne I. 1. Nucléus bifacial. 2–4. Éclats de plein débitage discoïde. 5. Nucléus Levallois préférentiel. 6. Nucléus Levallois centripète. (Dessins : C. Santagata).

environment relatively poor in flint at that time. These rocks were collected in varied environments (colluviums, alluviums) close to the site. Levallois, discoid and other core conceptions, as well as shaping, were applied to these raw materials, depending in part on the quality of the rocks.

4.2. Volcanic rocks reduction sequences

At Payre, the basalt pebbles were minimally shaped (or flaked) despite the fact that the reduction sequences are generally complete, except for the large flakes produced outside. The petrographic features of volcanic rocks are not always conducive to a long-term production. Cores or chopper-cores were frequently left with a flat surface. Small flakes are largely unretouched. In unit D, where the basalt ratio increased, the change of proportion between flaking/shaping might reflect a change in basalt management or different needs. The size of the products (from the first phases to debitage optimal phase) shows wide diversity I (11–60 mm). Cortical flakes are the largest products.

At Sainte-Anne I in contrast, blanks are generally exhausted and the flaking sequences are complete, whether opportunistic or predetermined. For all the raw materials, flaking produced homogeneous dimensional values (11–30 mm) and products with similar morphologies.

The lithic series are characterized by several production systems including several technical options. These more or less elaborate options were implemented according to the lithotypes, but elaborated and constraining flaking methods (Levallois and discoid) are predominant. These cores were managed by rigid or flexible conceptual operative schemes. Technical variability during flaking is due to the diversity of the rocks. The predominance of the discoid method reduced knapping accidents and assured a high number of end-products (Boëda, 1993). Besides these flaking modes, other methods and shaping modes were occasionally applied to the series (Santagata, 2012). Cores are often exhausted and left with a flat flaking surface.

Most of the flaking reduction sequences in Sainte-Anne I took place *in situ*. Production out of the site probably exclusively involved heavy-duty tools and a few big flakes secondarily shaped, used and broken at the site (presence of debris and handaxe points). The lack of initial shaping products might suggest that some handaxes were mobile tools produced outside or used as raw material reserves, as the final removals could indicate by their form and location (*cf.* Turq, 2001).

4.3. Volcanic rocks versus other raw materials

At Payre, volcanic rock strategies share some common features with the other stones, apart from flint. In all the units, flint is the most abundant material, mainly managed by unifacial discoid flaking, associated with other core conceptions, depending on the units. Reduction sequences on fragments of nodules or flakes on local and semi-local flint are complete. Some flint flakes come from long distances (60 km) sources and are related to partial operative schemes. The series combine large flakes (brought already knapped) and small flakes (flaking *in situ*), retouched or not, including scrapers and points made on middle-size flakes coming from the discoid core technology. Scrapers are made on any type of flakes while points are more frequently made on triangular flakes, including pseudo-Levallois flakes. In unit Ga, discoid cores and various types of cores on flakes and fragments characterize the series (Baena et al., 2016). A very large bifacial tool on a flake may have been imported (flint from a source at 30 km). In units F and D, flaking is preferentially discoid and unifacial on flakes. Cores are exhausted. Other types of cores complete the series: Kombewa, polyhedral, unipolar or *semi-tournant* (flaking around the periphery of the core).

As for basalts, all the local raw materials were partially exploited *in situ* (importation of quartz and limestone flakes). Large flakes made of basalt and quartzite were imported (Moncel, 2001; Moncel, 2008a, b; Moncel et al., 2008). Quartz was brought to the site as pebbles, but above all as selected products knapped out of the site (Moncel, 2008a, b; Moncel et al., 2008). Some cores (unifacial and bifacial pyramidal discoid) attest to knapping activities inside the cave. Pointed flakes and long flakes were selected. The largest flakes are retouched, although most flakes are unretouched. Limestone is very rare, present mainly as pebbles or large flakes, sometimes shaped. In units F and D mainly, thin and sharp flakes were produced out of the site and are generally unretouched.

In unit G, quartzite is present as large cortical flake-tools (flaked outside on big pebbles) or pebble tools. In units F and D, quartzite flakes are rare, retouched or not, flaked off-site or *in situ* (resharpening). In unit D, there are whole or broken pebbles and small and unretouched flakes. Crushing marks on the edges suggest intensive use of these objects.

At Sainte-Anne I, flint is rarer than at Payre and volcanic rocks have been preferentially used (Raynal, 2007). Several operative options were applied to local types of flint, often similar to those used for basalt and phonolite. The main flint resource, lacustrine Sannoisian flint collected in the Puy-en-Velay basin from local sources, was managed by recurrent unipolar or bipolar Levallois conception on nodules or slabs. For its different varieties, a preferential Levallois chain was applied with elongated products due to slab knapping. Cores of very small dimensions exist (Fig. 1). Flaking was also opportunistic – orthogonal bipolar – (unit J1) on different types and morphologies of blanks. For some varieties of lacustrine flint, unipolar or bipolar Levallois technology ended with a preferential flake, depending on the morphology of the blank. The Levallois products used the naturally flat surface of the slab and covered the entire surface. Bifacial discoid flaking was adapted to the morphology of the blank.

In both units, flaking on quartz is discoid, unifacial and bifacial, producing lateralised backed flakes. Occasionally, for quartz and volcanic rock, percussion on an anvil is attested (double and opposite percussion impacts on the cores).

4.4. Adaptation to the available raw materials?

In both sites, over time, Neanderthals used the local and regional subsistence sphere and collected all the available materials. The use of high-quality local flint (even in small quantities at Sainte-Anne I) and exogenous flints at both sites indicates a structured land-use which was adapted to the surroundings geology and relief constraints. Flint procurement shows that Neanderthals exploited a vast territory on the southeastern margins of the Massif Central. Volcanic rocks were collected from the local surroundings and their proportions reflect both their availability and quantity around the site and the need for heavy-duty tools.

At Payre, where flint was abundant, local basalts were gathered as basalt cobbles at the foot of the site on alluvial terraces. Specific and opportunistic management (large heavy-duty component and some flaking) was applied to these rocks, similar to that used for local quartzite, whereas local limestone and quartz were above all flaked (Moncel et al., 2008). The *chaînes opératoires* applied to basalt were mainly short and opportunistic (diverse types of management observed in the different units). Fine-grained limestone and flints, with similar petrographic characteristics, were preserved for predetermined core conceptions and quartz, although more coarse-grained, was also employed in the same way. It is probable that the medium and poor quality of the volcanic rocks and their quantity at the foot of the site, as well as the dimensions of the available cobbles and the large flakes, partly explain the predominance of heavy-duty tools at the site. It seemed likely that each type of raw material at Payre was aimed at specific purposes due their geological characteristics. However, preliminary micro-wear analyses on quartzite indicate the contrary (Pedergnana et al., 2016).

At Sainte-Anne I, where flint was less abundant, elaborate and diversified schemes were applied to local volcanic rocks. This management was carried out in parallel to similar and complex flaking reduction sequences *in situ* for the other local raw materials and flint. The two main archaeological units J0–J1 and J2 can only be differentiated by the presence or absence of handaxes. The technical strategies indicate the mastery of different core conceptions adapted to the petrographic features of the rocks. The characteristics of basalt and flint allow for flexibility in technical choices and the management of classic systems of flaking. The methods applied to flint needed to be occasionally adapted to the morphology of the blanks (slabs for instance). On the other hand, phonolite, trachy-phonolites and quartz required a broader and more simplified approach and the particular foliated structure of the phonolite resulted in a specific morphology of the artefacts.

5. Conclusions

Technological analyses of artefacts made of volcanic rocks at Payre and Sainte-Anne I confirm the high degree of flexibility and adaptability of Neanderthal know-how to the geological resources since the early middle Palaeolithic (from MIS 11 to 6) (Moncel et al., 2016). Neanderthals had a strong knowledge of the geological potential of the area and they developed a strategy of "collector" of all the available raw materials (Fernandes et al., 2008; Raynal et al., 2012).

The mid-mountain cave of Sainte-Anne I and the site of Payre, located in the low plateaus bordering the Rhône Valley, share similar features: numerous types of raw materials collected, different technical strategies and choices of reduction processes adapted to the petrographical and morphological characteristics of the raw materials. The two sites belong to a same regional area and the absence of topographical barriers between the Rhône corridor and the plateaus of the south-eastern side of the Massif Central (Raynal et al., 2005) certainly promoted mobility and common technological and subsistence strategies over time (Daujeard and Moncel, 2010; Daujeard et al., 2012; Fernandes et al., 2008; Raynal, 2007; Raynal et al., 2012, 2013).

In this context, the volcanic rocks were not considered as a makeshift resource, but as a complementary material collected for its petrographical nature and for economical or functional reasons. Some tools or end-products on volcanic rocks show specific morphologies from predetermined reduction processes (Moncel et al., 2008; Raynal et al., 2013; Santagata, 2006, 2012).

Lithic assemblages from early middle Palaeolithic sites express a combination of human technical aptitudes, local mineral resources and needs, depending on the nature and function of the sites. Raw material management often depends on technological parameters and raw material format (Baena et al., 2016; Bernard-Guelle, 2005). From the MIS 11 to 6, the diversity of strategies announces the late middle Palaeolithic regional traditions (Moncel et al., 2016).

The early middle Palaeolithic series we studied indicate an adaptation to the lithological variability of the territory and the coexistence of flaking and shaping chains in different proportions. It is likely that Neanderthal petrographic choices in this area were determined primarily by the aims of knapping and secondarily by the morphologies of the blanks, rather than by the lack of quality stones in the nearby environment. When flaked, some local raw materials of different petrographic nature had a similar behaviour than flint and technologies applied produced similar results (some basalts at Sainte-Anne I, quartz and limestone at Payre).

The series belong to the early middle Palaeolithic (up to MIS 5) characterized by the development of elaborate core conceptions and standardized end-products, such as Levallois core technology (Moncel et al., 2011) applied and mastered at Sainte-Anne I, on fine-grained volcanic rocks and flint.

The heavy-duty component is also part of these assemblages, possibly representing the remnants of earlier traditions (Hérisson, 2013; Moncel, 2001, 2003; Monnier, 2006; Jaubert, 2001; Soriano, 2001). These tools are made on local or semi-local (flint) stones at both sites, on large flakes or pebbles. They were partly imported but some bifacial or unifacial tools were produced *in situ*.

In a technological context where the aim was standardized, diversified and predetermined flaking, the wide morpho-technical variability of the handaxes in various raw materials including volcanic rocks, gives perhaps a specific status to these tools, rather than a cultural role, regardless of petrographic types and quality. This diversity cannot be evaluated in terms of regional traditions, but rather in terms of types of land-uses, activities requiring resharpening or specific forms, and raw material aptitudes (Conard, 2001; Delagnes, 1992; Matilla, 2004; Moncel, 2008a, b; Rigaud, 1988; Roebroeks, 1988; Roebroeks et al., 1997; Tuffreau and Somme, 1988).

The use of diverse local rocks, including volcanic rocks, and exogenous flints from more distant outcrops, the adaptation of core conceptions and shaping modes to the quality and availability of raw materials, regardless of stone types and proportions in both sites, demonstrate the capability of Neanderthals to avail of all their surroundings offers. Volcanic rocks were not merely convenient stones when flint lacked. Specific strategies were applied to them, sometimes similar to those involved in flint and other stones flaking and shaping, showing that they were considered as useful as flint or other raw materials.

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