Twenty-five Years Excavating Flint Mines in France and Belgium: an Assessment

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Abstract: Twenty-five years of experience in excavating flint mines allow us to give a methodological overview about sites characterized by the sheer depth of some structures, the often vast extensions of the deposits and the specialised activities that were carried out there. By comparing operations undertaken up to fifteen years apart, the importance of accurate stratigraphic and planimetric records becomes clear. Palaeoenvironmental approaches probably have to be multiplied in view of the results obtained when sampling is systematic. If the use of a mechanical excavator is inescapable to create large geological cross sections and allows the excavation of a large number of structures, an agreement emerges to consider that its exclusive use should be avoided. It should be regarded as a complement to be employed once a certain number of previous stages have been completed.

Keywords: flint mines, geological trenches, 3D mapping, knapping workshops, mechanical excavation, palaeoenvironment

Introduction

This paper provides the opportunity to offer an assessment of the archaeological experiences gathered on flint mines excavations during the last 25 years in France but also in Belgium. Methodology is a fundamental aspect when studying these sites because their specificity – on which we will come back later – places them in a distinct category of archaeological features. The feedback on our experience proposed here is fundamental in view of the challenge of development-led archaeology and more generally of research in this field. Indeed in the 1980s, research on this type of sites was lagging in France as during this decade only one planned excavation was under way at Bretteville-Le-Rabet, Calvados district (Desloges 1986). Besides, the enthusiasm for these mining sites, observed in the late 19th and early 20th centuries in other European countries such as Belgium and Great Britain, was not as strong in France. However, a few sporadic excavations undertaken in the years 1950–1970 at Hardivillers-Troussencourt, Somme district (Agache 1959), Nointel, Oise district, Saint-Mihiel, Meuse district (Guillaume 1975) or Veaux-Malaucène, Vaucluse district (Schmid 1980) and Salinelles, Gard district (Dijkman 1980), published in two general overviews, one for France (Soulier 1973), the other for Europe (Weisgerber *et al.* 1980), allowed to maintain some small scale activity,

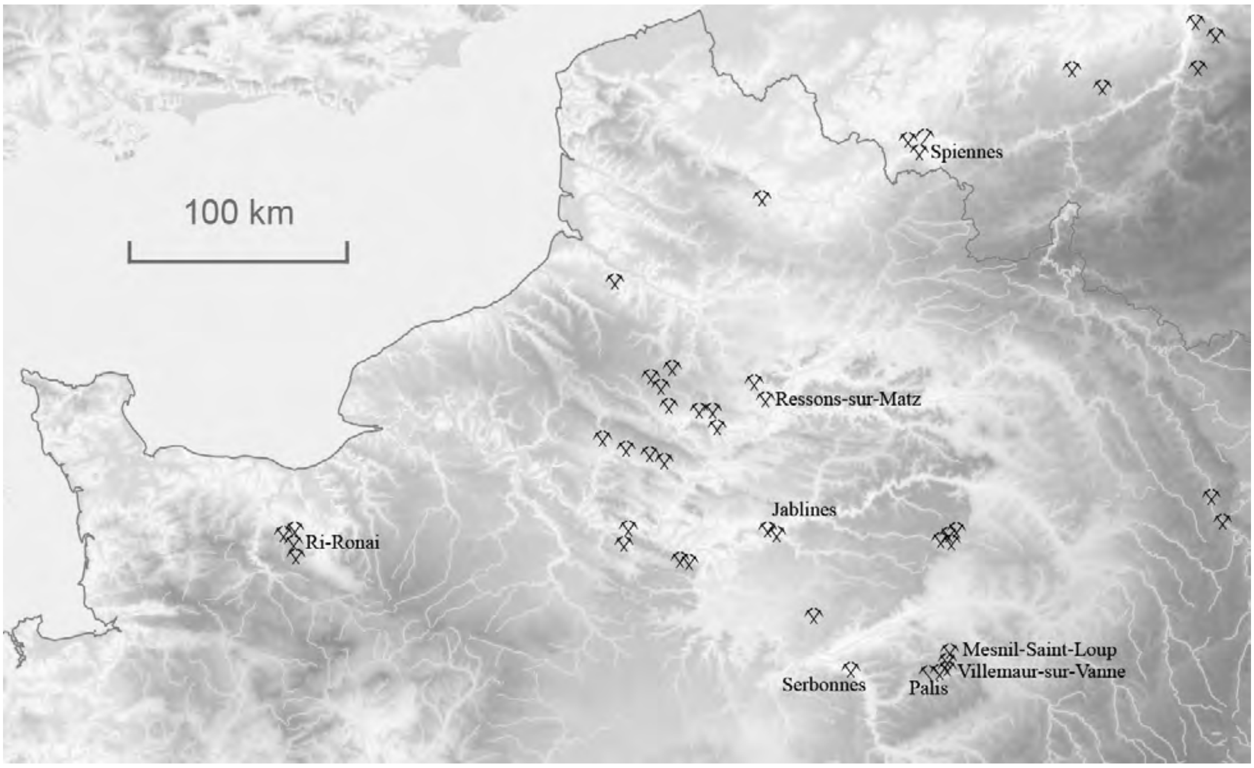

Fig. 1. Localisation of the flint mines in Northern France and Belgium. CAD: F. Bostyn, background map: F. Giligny.

with the means available at the time, in this research field. The discovery and the excavation of mining sites in the late 1980s and the next two decades during large scale development-led archaeology operations eventually allowed to renew and revitalise this specific aspect of research but also made it necessary to start a reflection on excavation methods adapted to the context of rescue archaeology. Besides, within the 25 years time span envisioned in this paper, technological evolutions took place, providing archaeologists with new analysis tools. Sites to which reference will be made allow for the confrontation of various experiences over time (Fig. 1): Jablines 'Le Haut-Château', Seine-et-Marne district (Bostyn and Lanchon 1992), Serbonnes 'Le Revers de Brossard', Yonne district (de Labriffe and Sidéra 1995a), Pâlis 'Le Buisson Gendre', Aube district (de Labriffe and Sidéra 1995b), Villemaur-sur-Vanne 'Le Grand Bois Marot' (de Labriffe *et al.* 1995b) and 'Les Orlets', Aube district (de Labriffe *et al.* 1995a and 1995c), Ri-Rônai, Orne district (Ghesquière *et al.* 2012) and Mesnil-Saint-Loup, Aube district (Hauzeur *et al.* 2010). Unfortunately the growth of development-led archaeology has mostly put an end to planned excavations in this research field as in others. Therefore the research at Spiennes, Mons district, in Belgium (Collet *et al.* 2008) was deemed appropriate to be integrated in this paper. It combines both planned and rescue excavations, since the discovery of the site in the second half of the 19th century.

Specialised sites, singular structures and specific excavation problems

It is necessary to review the subject of mining sites because these archaeological deposits have their own specificities which, in some ways, make them exceptional. The vast size of these sites is one of their characteristic features, which finds manifestation in a high number of structures. For example the size of the flint mines of Spiennes is estimated at 100+ hectares, that of Bretteville-le-Rabet at 60 hectares, those of Jablines and Villemaur-sur-Vanne 'Les Orlets' at 35 hectares. If the exact number of archaeological structures cannot be precisely defined, estimates based on direct information such as aerial photographs or on proxy data such as extrapolations based on limited topsoil stripping give numbers like 30,000 shafts in Bretteville-le-Rabet, 20,000 in Villemaur-sur-Vanne 'Les Orlets', 9000 in Ri or 5000 in Jablines.

It could be argued that numerous archaeological sites share these characteristics (site extent and large number of features) but in the case of flint mines the fact that they consist of huge underground remains compounds the problems linked to their exploration. Indeed if some features are simple pits, the majority of the mining structures appears as vertical shafts that can reach 15 metres deep (as in Spiennes) with horizontal galleries dug on several metres at their bottom. Besides the sheer amount of excavation that such structures generate (for instance sediment volume extracted from a 7.5m deep, 3m wide shaft is 53m^3 not counting galleries and soil expansion), the handling of sediments in confined spaces is extremely heavy and technical issues linked to the disposal of excavated soils are very real. If this approach enables us to grasp the problems faced by prehistoric miners, security issues in underground excavations are constant and are exacerbated by the fact that the ground was destabilised by prehistoric mining. The lack of natural light and/or of fresh air is also to be taken into account.

Another challenge lies in the complexity of these mining structures which is linked with the geological context of the raw material. The quality of the flints can vary strongly over a distance of a few metres and prehistoric miners had to adapt permanently to the geological context. The variability of the mining structures has direct consequences on the work of the archaeologist. He is unable to predict the underground organisation of the mine and this necessitates a continuous responsiveness.

The specificity of the structures, the specialized and intensive nature of raw material mining and the mass production of tools and tool blanks create a plethora of archaeological remains the study of which is paradoxically a thankless job. They mainly consist in flint knapping waste and relate to the primary processing of the raw material. The management of this huge quantity of artefacts, both in terms of excavation strategy and later study methodology, is a general concern and an additional burden on how a flint mine excavation is operated. Paradoxically, while lithic artefacts are abundant, few can give a direct dating of the use and abandonment of the mine. This real handicap is mostly significant regarding field decision-making during the excavation and can only be overcome thanks to alternative *a posteriori* dating methods, notably radiocarbon dating.

The research goals of a flint mine excavation are manifold but we will focus only on those related to development-led archaeology. It should be recalled, though, that the three main research axis when excavating a flint mine all focus on the raw material mined and refer to the definition of the geological context and the gitology of the coveted material, procurement strategies and extraction techniques implemented to obtain it and the ensuing processing methods of the raw material. Understanding the organization of mining, both underground and on the surface, is a necessary aspect of all archaeological excavations of a flint mine. Two complementary levels of analysis should then be developed: on the one hand intra-structural considerations concerned with questions relating to morphology, mining processes, gallery operation, waste management, archaeological content and on the other hand the inter-structural approach which consists in the study of groups of adjacent structures. At the scale of the whole mining site, the nature of the questions asked changes as the objective is to understand the development of the site through time both in terms of spatial extent and in terms of mining techniques, to highlight possible hiatuses in site-use and potential mining structures overlaps. Combining scientific issues and excavation methods is a complex exercise because parameters vary from one site to the other and because the challenges exposed earlier lead to the conclusion that the minute exploration of such sites in their entirety is impossible, be it in the context of a development-led excavation or a planned excavation. If, when there is no threat of destruction, one can afford a detailed hand-excavation knowing that only a tiny part of the site will be explored, in a development-led context the short-term destruction of a large amount of archaeological features imposes very different intervention procedures. If a number of approaches have proven essential other issues are still open to question such as fieldwork choices to be made (as opposed to exhaustive excavations), choices which concern the mining structures but also the surface knapping floors when they are preserved, as well as the excavation method to be used, notably what should be allocated to mechanical or hand-excavation.

By confronting various field experiences, we will discuss the pros and cons of the excavation methods implemented and we will try to conclude with a hierarchisation of the established principles over procedures that are still open to question.

Methodological approaches

The major linear projects of the Eighties: First methodological achievements in a development-led context

Drawing on previous experiences in France but also across Europe, the first large-scale development-led archaeology operations on flint mines were undertaken as part of the development plans of the '*TGV-Nord et Interconnection*' (High Speed Train project) and of the A5 highway.

Jablines 'Le Haut-Château' excavations

The '*TGV-Nord*' right-of-way and above all that of the '*Interconnection*' ran across the Jablines 'Le Haut-Château' mining site, district Seine-et-Marne, which was known beforehand (Bulard *et al.* 1986). Designed in advance, the intervention was planned to last 12 months between August 1989 and September 1990 and,

Fig. 2. Jablines 'Le Haut-Château', Seine-et-Marne district. The excavation of the deepest mines was undertaken in two phases: the excavation of the vertical access shaft then the excavation of the extraction galleries after the removal of the sterile substratum so as to work in better conditions. Photo F. Bostyn, Inrap.

from the start, provided for a complete stripping of the development project right-of-way, which revealed severe surface erosion except in a slight depression where knapping workshops next to mining shafts were preserved (Bostyn and Lanchon 1992). Both the north and the south boundaries of the mining site have been reached. The alignment of the HST route following the natural slope of the land, the transect through the mining site offered the advantage, by cutting the site almost in half, of providing a geological cross section of more than 100 metres long. It has not been considered as an analytical method for the mining structures unlike what has been done on the A5 highway. So as to preserve for as long as possible the integrity of the site and to limit the risks of accidents, the geological cross section was undertaken at the end of the field operations. Taking into account the surface distribution of the 766 mining structures, the choice was made to select groups of shafts spread over the whole stripped area. The excavations showed that the further south one goes up the slope, the deeper the shafts are sunk. To the south shafts as deep as 7.5m were discovered and to the north only shallow pits were found, in direct relation both to the topography and the gitology. Hand-excavations were undertaken by opening half of the

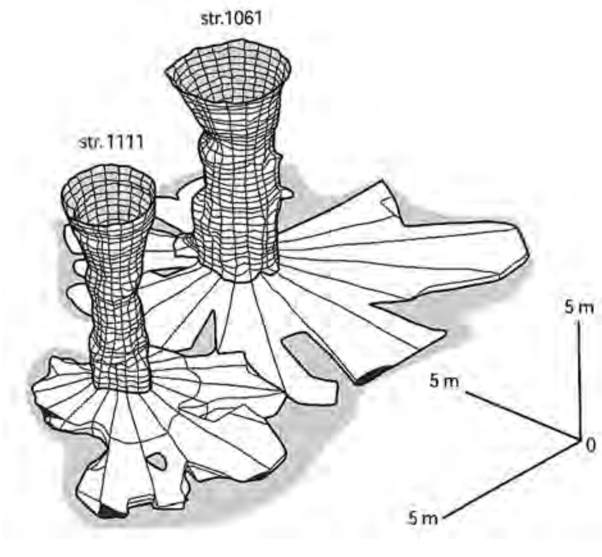

Fig. 3. Jablines 'Le Haut-Château', Seine-et-Marne district. 3D view of a deep flint mine. This pictorial allows not only to visualize the overlapping of the structures but also to determine the volume of bedrock that was removed and the quantity of raw material collected.

shafts so as to record the stratigraphy of the backfills accurately and collect the artefacts by stratigraphic unit. But faced with the growing depth of the structures it was decided, in two sectors, to remove the substratum down to the roof of the galleries, once the excavation of the vertical shaft was over (Fig. 2). In order to get a more dynamic view of those complex structures, a technique to record the outlines of the mines was implemented so as to produce a three-dimensional representation. The archaic method of manual recording used was time-consuming both in the field and during the processing of the data with insufficient computing resources, but the end results were up to the expectations and allowed a different perception of the mines (Fig. 3).

This method allowed a thorough exploration of the selected features in a safely manner and to accurately record the artefacts. It also made possible the recording of more elusive traces such as tool marks on the walls and evidence of wooden supports in the backfills... But only 56 mines could be excavated, or less than 10% of all the structures that were destroyed. If the value of the data obtained is undisputable, the total lack of information on the other shafts is the weakness of the chosen method and can be contested. A single knapping workshop was excavated by one square meter units, further subdivided in 25 smaller squares. No field plan was done and the artefacts were collected in small 20cm wide square units in three successive phases. This method did not hinder further studies.

One of the goals of the excavations was to conduct palaeoenvironmental analysis, which was done thanks to a systematic sampling of the backfills. The results were more or less successful depending on the materials sampled, generally related to the poor conservation of remains in a calcareous context (this is especially true for palynology and anthracology). The scarcity of comparative data and partly contradictory results prevented the optimization of data interpretation at that time.

The excavations of the mines on the A5 highway

Archaeological investigations led prior to the A5 highway construction, between Melun (Seine-et-Marne district), Sens (Yonne district) and Troyes (Aube district), took place between 1988 and 1992. On the 144 km of the right-of-way no less than four mining sites were discovered in Serbonnes 'Le Revers de Brossard' (de Labriffe and Sidéra 1995a), Pâlis 'Le Buisson Gendre' (de Labriffe and Sidéra 1995b) and Villemaur-sur-Vanne 'Le Grand Bois Marot' (de Labriffe *et al.* 1995b) and 'Les Orlets' (de Labriffe *et al.* 1995a and 1995c). Unlike the flint mine of Jablines, the four 'A5' sites were found during the diagnostic phase, 'Le Grand Bois Marot' being the only mining site that was expected to be discovered. As a result, the resources allocated to each of the other sites were less important. These external parameters, especially the large number of sites and the lack of resource previously assigned, led to adapt the archaeological investigation strategy (de Labriffe and Thébault 1995). It was decided straight away to mechanize the excavations in order to collect the data as quickly and as cost-effectively as possible. Hand-excavations were nevertheless planned, in particular to work on parts of shafts that were intersected by the mechanical operations and on possible knapping workshops.

Fig. 4. Villemaur-sur-Vanne 'Les Orlets', Aube district. A large mechanical trench was dug across the A5 mining sites to facilitate stratigraphic and planimetric drawings as well as the excavation of the remaining parts of the shafts. Photo P.-A. de Labriffe.

Once the stripping of the soil and the mapping of the features were carried out, it was decided to undertake the mechanical digging of large trenches on the whole length of the sites, that is several tens of metres to a depth of 6 metres and as wide. The objective was to recreate the context of discovery of the flint mines of Spiennes, brought to light at the end of the 19th century during the digging of a trench for the construction of a railway.[1]

Apart from the comparison to be made with Spiennes, the expected benefits of these trenches were supposed to be numerous. Insofar as the right-of-way crossed three of the four sites perfectly transversally, following the slope, they were first meant to obtain an overview of the sites and to document a large number of mining features. It would have been possible to recognize their general morphology, the backfilling processes and to understand their relation with both the substratum

[1] The idea of digging large trenches, never repeated since Spiennes, was considered, half jokingly, when Prof. Jacek Lech was visiting Serbonnes (in the second semester of 1989) during the diagnostic phase, the first mining site to be identified.

and the raw material deposits. The width of the trenches would also provide the necessary distance to analyse and record the stratigraphy of the shafts and the pits visible in the profiles and would also facilitate their excavation (Fig. 4). The trench would also contain the excavation waste so as to avoid long and tedious handlings in the tight spaces of the mining structures.

However, when confronted with the realities of the field, that method of intervention could not be implemented as efficiently as hoped. As a matter of fact the execution of the trenches was sometimes hindered by the lack of stability of the walls or of the structure backfills. During the trenching, while several dozens of mining structures were impacted, it was sometimes difficult to accurately attribute artefacts (knapping waste, axe roughouts, deer antler tools) to specific contexts. Once the trenches were completed, drawing was sometimes made difficult by the sheer size of the profiles and the complexity of the stratigraphy but, by contrast, work was made easier by the possibility to step back and have a larger view. The trenches also greatly facilitated the excavation of the remaining part of the structures.

In the end and despite the few difficulties referred to above, the informative contribution of the trenches turned out to be very positive and provided an unparalleled picture of the sites. The whole geological context of the site, sometimes complex, could be assessed as well as the close relation between the mining structures and the raw material and the mining techniques strategy (de Labriffe 2006). Another benefit of the trenches was to document very quickly a fair number of mining structures: more than 20 at 'Le Grand Bois Marot' and 50 at 'Les Orlets' out of 800 brought to light (Fig. 5).

It must be specified that, undertaken at the beginning of the 1990s before archaeology was structured as it is today, trenching was sometimes done in breach of safety regulations. It would undoubtedly be tricky to consider this operation the same way nowadays.

Only Villemaur-sur-Vanne 'Le Grand Bois Marot' yielded occupation layers and well preserved knapping workshops on the whole right-of-way (between twenty and thirty). Within the framework of limited resources only two of these chipping floors were excavated, of which the largest covered close to 35 square metres. The clusters were first excavated then the artefacts were recorded and collected by successive layers in ¼ square metres units. Artefacts, in considerable quantity (more than 800kg for the main cluster), were next washed with a high-pressure cleaner, sorted, weighted, and categorized according to a simplified typological inventory (Augereau 1995). No counting and refitting were done.

These first development-led excavations experiences, while making distinct strategic choices and implementing different methods, allowed to test new techniques but above all to make indispensable a number of steps such as complete topsoil stripping of the right-of-way, geological study with deep trenching or stratigraphical study of the backfills. The positive and negative aspects of each of these methods were discussed as well, in particular the more or less heavy use of the mechanical excavator. In any case one of the major problems encountered in the study of those mining sites was their dating, which could not be solved altogether due to a lack of means to pay for radiocarbon dates.

More recent experiences and technological evolutions

New development-led excavations of mining sites in France (those of Ressons-sur-Matz, discovered in 2005 were left untouched for preservation, Beaujard and Bostyn 2008) took place some fifteen years later, allowing to learn from past experiences but also to benefit from technological developments.

The experience of Ri-Rônai, Calvados district

On the flint mines of Ri-Rônai, excavated in 2007, 30 to 50 shafts were expected after pre-construction survey, but the 2.2 hectares archaeological topsoil stripping led to the discovery of 550 shafts. The excavation was planned to last 6 months with an average field team of 10 archaeologists and had to be adapted according to the new parameters without altering the funding envelope assigned to the operation.

The scientific management plan written by French National Institute for preventive Archaeological Research (INRAP) provided for the exhaustive excavation of the mining structures identified within the right-of-way. It was decided by agreement with the Regional Archaeology Service to maintain that objective while keeping a recording level consistent with the management plan. In this context, mechanisation appeared unavoidable. The mixed use of mechanised and hand-excavations allowed the exhaustive study of the site with the exception, for obvious safety reasons, of a few shafts located near the edge of the study area.

Nearly 530 shafts could be studied, among which about 40 were less than 1m30 deep and were hand-excavated so as to evaluate the results bias between the two techniques. An average of 5 shafts a day was excavated mechanically using a systematic methodology planned in advance. The shafts were cut in half as far as possible, given their close proximity to one another (assuming that some structures could overlap, longitudinal cross sections were undertaken). The artefacts discovered in

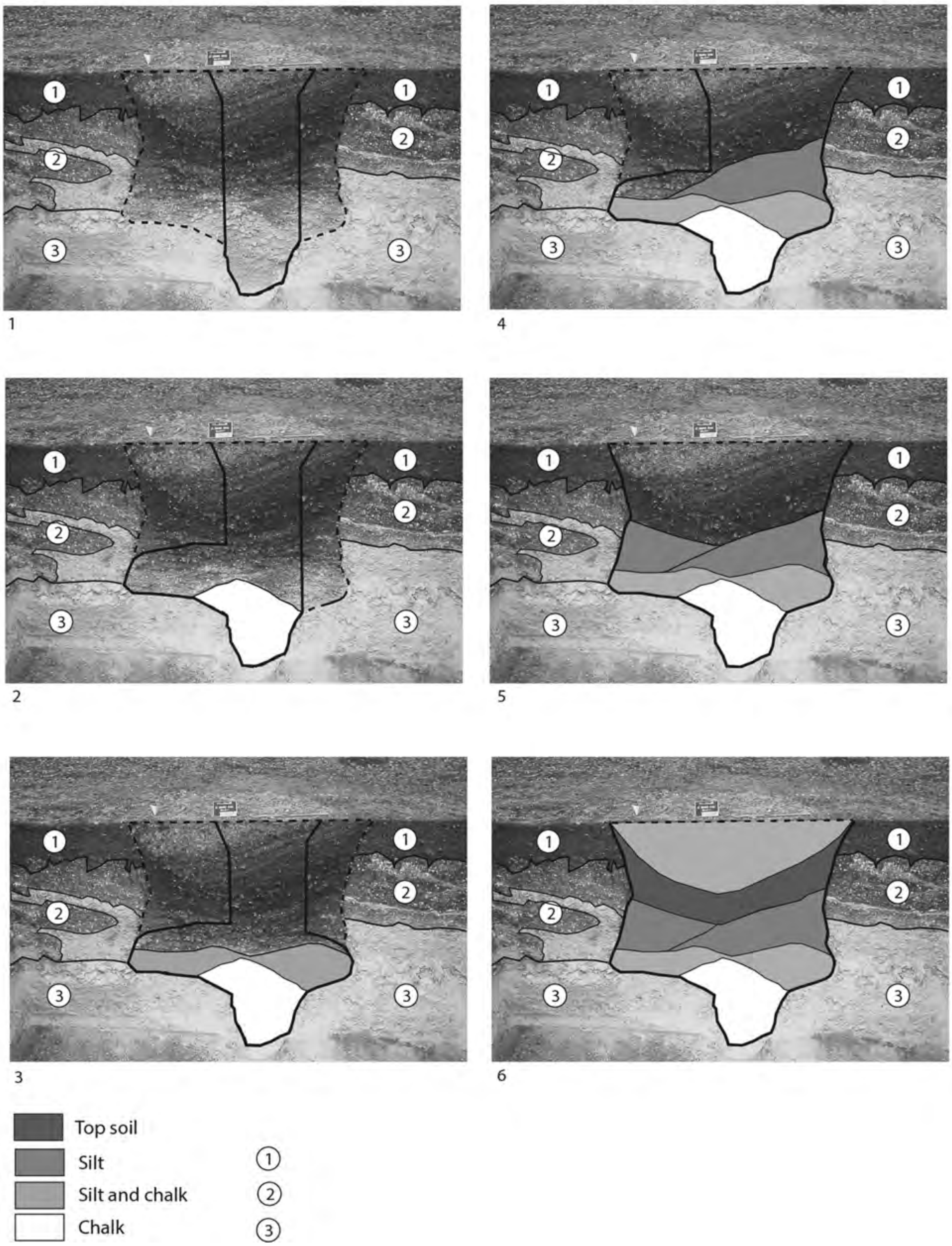

Fig. 5. Villemaur-sur-Vanne 'Le Grand Bois Marot', Aube district. Interpretative sketch of the digging and backfilling processes of a shaft.

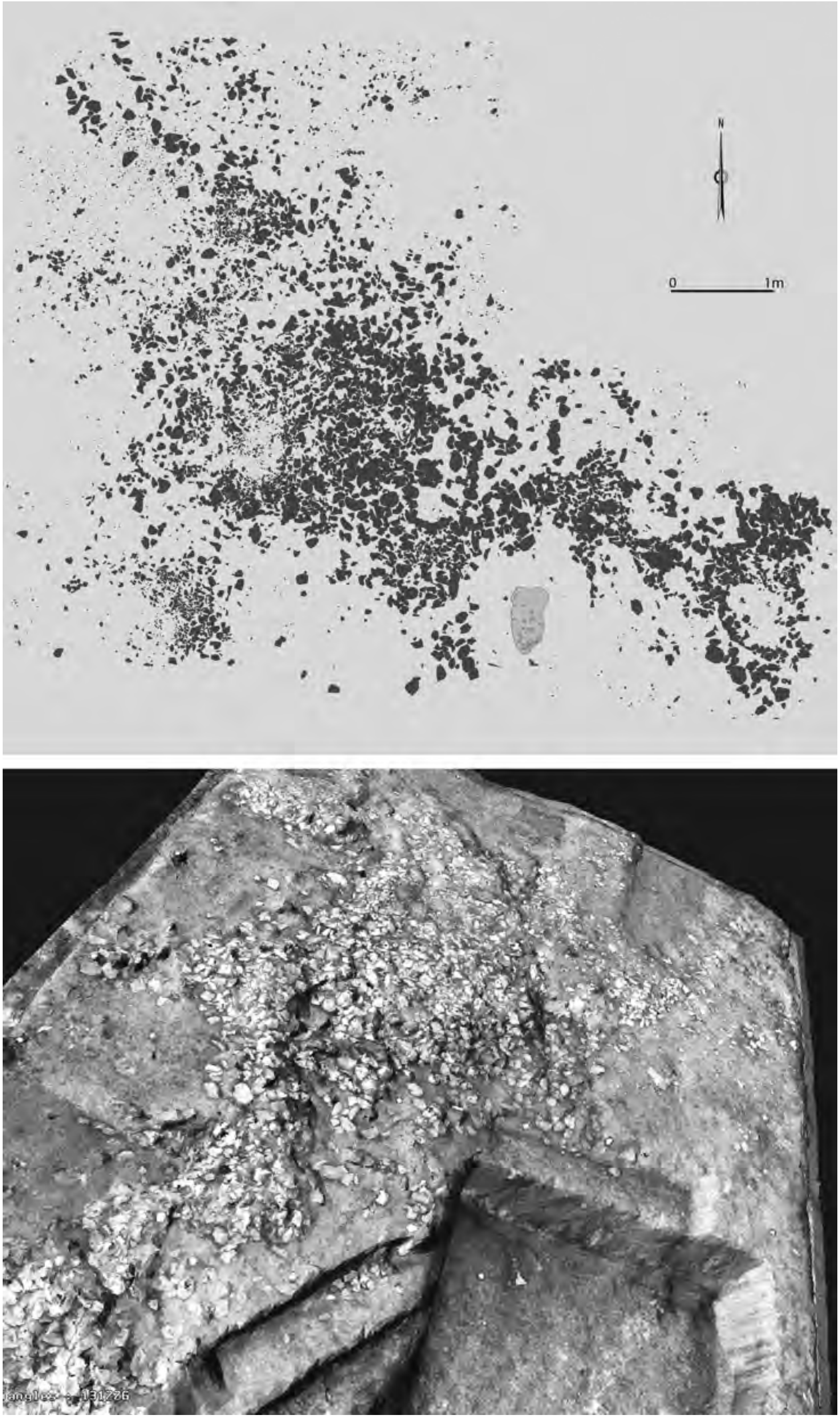

Fig. 6. Ri-Rônai 'Le Fresne', Orne district. A–plan layout of the large knapping workshop discovered in the loess; B–photography of the 3D scan of the knapping workshop.

the backfills and the width variations of the structure were manually recorded, for each excavation level, on a 1/50 scale polyester copy of the horizontal plans. Stratigraphic cross sections were recorded before excavating the other half of the shafts as far as possible, according to the proximity of the structures (220 cross sections). The knapping waste deposits found in the backfills of the shafts and the large knapping workshop preserved in the loess cover (Fig. 6) were, for some 50 of them, hand-excavated and recorded with a drawing frame. The few other knapped flint clusters found during mechanical excavation were collected solely for the lithic study.

Fig. 7. Mesnil-Saint-Loup, Aube district. Density of the extraction features after the topsoil stripping of the whole excavated area. View from a stationary balloon down the valley of the river Vanne. Photo: Dombe-Rhône.

A large number of radiocarbon dates were obtained on the site of Ri-Rônai. The first 40 dates were included in the initial management plan and another 100 were imposed by the *Commission Interrégionale de la Recherche Archéologique* (CIRA) prior to the publication. Eventually only 12 more dates were made. Both series (standard dates obtained on deer antlers) are quite homogeneous, clustering approximately around two centuries (between 4000 and 3800 cal BC), with the exception of one date relating to a later mining phase on the site. The scientific justification of the second series of dates is therefore not obvious given the homogeneity of the results.

The main cluster of hand-excavated shafts was recorded with a 3D scanner. If the technique allows to obtain stratigraphic profiles in every desired direction, it is of moderate help given the restricted access to the software. Once the picture is horizontally rectified it is possible to obtain an accurate view of the extension of Neolithic diggings but it brings few new data compared to the 1:100 scale plans done manually during the mechanical excavation. Likewise, the vertical view does not add anything compared to a classic, even schematic, cross section. A 3D scan, however, remains a top-notch didactic and aesthetic tool. Above all the technique makes it possible to obtain a recording of a set of shafts with accuracy to the nearest centimetre and to constitute high-quality archives. This documentary source is a good supplement to the photographs and controlling the lighting brings out specific features. Furthermore, the 3D visual rendering of the large knapping workshop is complementary to the stratigraphic profiles and allows to highlight the slight domes formed by each knapping stations. In this case the tool is of interest to illustrate the field observations and records.

Is there anything that would have justified a hand-excavation in Ri-Rônai? Regarding the mining sites, given their peculiarities, the question is not insignificant. Hand-excavation enables you to recover artefacts in somewhat better condition (notably unbroken deer antlers) and to prevent them from ending up with the excavation waste. However, the homogeneous characteristics of the structures, of the mining and backfilling methods, and of the tools used, leave little room for unexpected data (scarce faunal remains and potsherds). Moreover, identifying the edges of manually excavated structures is sometimes very difficult and we can never be sure to follow the exact limits of the Neolithic diggings (several shafts were dug in older mining backfills). Lastly, safety regulations are never altogether respected (overhangs, galleries). Ultimately, in the case of the mines of Ri-Rônai, few factors would have benefited from the hand-excavation of the shafts and, in hindsight, it could be said that hand-excavation could have been restricted to the knapping workshops, the hearths and the deer antlers clusters. It is indeed these evidence on which the understanding of the way a mining site was operated primarily rely (did the miners make their digging tools on the site? what did they do with the extracted flint?) more than on the details of their mining methods, all broadly similar.

Full mechanical excavations at Mesnil-Saint-Loup (Aube district): an appropriate strategy for mining sites?

The case of a nearly all-mechanical excavation occurred recently on the occasion of an archaeological assessment on the mining site of Mesnil-Saint-Loup, in the region of Champagne. No mining site had been subjected to that type of procedure yet.

The mining site of Mesnil-Saint-Loup is located in the valley of the Vanne River on the same side as the Villemaur-sur-Vanne and Pâlis mining sites mentioned earlier, approximately 5km to the south-west. It belongs to the Mining Complex of the 'Pays d'Othe'.

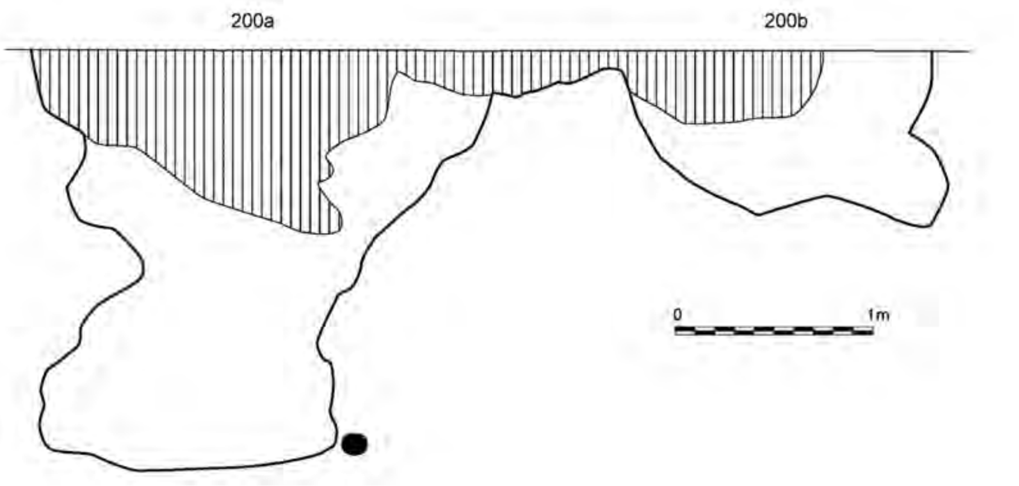

Fig. 8. Mesnil-Saint-Loup, Aube district. Sketch cross-section of the mining pits illustrating the outlines of the structure, the top backfills or 'pit cap' and the flint nodules in primary context. CAD Paléotime.

The pre-construction excavation affected a surface of nearly 8000m^2 and was conducted over nine weeks, in the spring of 2010, with a team involving seven people and the brief intervention of a geo-archaeologist (H.-G. Naton, Géoarcheon). More than 560 structures were discovered (Fig. 7), resulting in a density of approximately 800 structures per hectare. The quantitative and qualitative importance of the site was not anticipated during the diagnostic phase but we nevertheless met the objectives of the prescription. The average depth of the structures was 90 cm, with extreme values ranging from 20 to 285 cm and morphologies varying between simple mining pits to shafts with underground workings (Hauzeur *et al.* 2010). The site is chronologically very homogeneous, dated between 3900 and 3500 cal BC, with a high probability for a calendar age of 3700–3650 cal BC. The period during which the mining site was operated is in line with the other mining sites of the 'Pays d'Othe' and the mines of Serbonnes (Yonne district) and gives the term 'mining complex' its relevance. The raw material was extracted from several flint seams and the lithic production focussed on the making of axeheads, of which almost 400 roughouts were collected during the excavations. A large number of deer antler artefacts were also identified, essentially mining tools, as well as a few hammers made from antler burrs. No domestic item such as pottery was collected or observed.

So as to conform to the prescription, the excavation was entirely mechanized from the topsoil stripping to the emptying of the structures necessitating the constant use of the hydraulic excavator, equipped with a 80 cm wide toothless bucket so as not to impact the neighbouring features. About a hundred structures were 'excavated' in more detail as all the backfilling sediments were mechanically sieved through a 10mm mesh. Hand-excavation was exceptional and was never applied to a structure as a whole.

Once topsoil stripping was completed and the density of the features was known, the self-evident fact was that an average of fifteen pits had to be excavated each day! Each shaft was cut in two by the excavator, the bucket working in front of the cross section, as in Ri-Rônai. The circular path of the bucket created a more or less pronounced chamfer of the cross sections depending on the depth of the structures, which sometimes gave a misleading impression about their actual dimensions. A draft on a 1:50 scale was quickly drawn and as often as possible a photograph was taken (Fig. 8). The second half of the structures was systematically emptied and if necessary the field draft was adjusted.

In retrospect, it is fortunate that most of the features were actually shallow mining pits and that deep shafts proved to be few on the right-of-way. Fortunately as well the backfills were very similar with a typical and repeated stratigraphic sequence. Except for the shafts that were selected for mechanic sieving and a few other exceptions, only the most significant artefacts were collected in the excavator bucket: axehead roughouts, deer antler picks, flaked nodules... In spite of the mechanical excavation technique used on the site, traces of prehistoric mining tools could be observed on the walls of several structures.

The all-mechanical archaeological excavation is extremely destructive and obviously leaves you frustrated. Indeed, if one cannot deny the advantage of being able to excavate a site in a very short time frame and of obtaining a comprehensive overall picture of the mining features, the lack of qualitative data collected is undeniable. This extreme method does not allow either for detailed stratigraphical observations or for the understanding of the stratigraphic relation between the structures (overlaps, connecting galleries, etc.) and their volumetry. Even with mechanical sieving one cannot claim to an exhaustive collection of archaeological artefacts and *a fortiori* to their recording by stratigraphic units. To abide by the time constraints, the prescription objectives and to collect a maximum of data, excavations and recording procedures were not necessarily compatible with safety requirements.

The planned excavation, a small scale operation with high added value

Spiennes, located at the south of the Mons Basin in Belgium, was one of the first mining sites discovered in Europe. While most archaeological research was limited to the upper part of the structures, excavations of complete mines were exceptional. This is explained, here as on other sites, by the level of resource required for the investigation of such deep mining structures and the sheer amount of work involved. In Spiennes the shafts often reach a depth of 8 to 10m, sometimes even 16m, at the base of which mining galleries were dug. In 140 years of exploration, a mere 13 structures were fully excavated (Collet *et al.* 2008).

Recognized as World Heritage by UNESCO in 2000, archaeological operations are led on the site in view of its preservation. Interventions, even when undertaken prior to a development project, are kept to a strict minimum. Stripped areas are thus of limited surface (from 150 to 1500m² for the largest). Rather than resorting to fast and cost-effective mechanical excavations, the structures are most often excavated only on the impacted upper part. The major disadvantage stems from the fact that collected data are both occasional and fragmentary. More general results are expected over the long term thanks to the gradual build-up of data. In the absence of large stripped and tested transects, it is difficult to estimate both the number of structures and their spatial distribution. The general site gitology is difficult to understand as well but in Spiennes, fortunately, a large cross section was made available in the 19th century during the trenching of the railway and offset this problem.

As part of a limited excavation of two 9 and 10 metres deep mines at the end of the 1990s, the shafts were divided into quadrants and fully hand-excavated, which allowed the recording of two perpendicular cross sections. In order to have the necessary distance to be able to record the stratigraphical data in such a confined space, the excavation was undertaken by successive layers of a maximum thickness of 60cm in diagonally opposite quadrants. Thereafter the remaining quadrants were dug up to a depth of 60cm to obtain a flat surface and the excavation could proceed deeper. The cross section is thus created as the excavations progress. The excavations are not limited to the edges of the structure but expand beyond, both to obtain a more comprehensive view of the cross section and to be able to shore up the archaeological digs for obvious security reasons. The measures allowing the reconstruction of the inner volume of the shaft were undertaken according to the same methods as in Jablines. Hand-excavation was completed by systematic dry sieving of all the sediments through a 4mm mesh as well as the occasional collecting of sediment samples to be wet-sieved in the laboratory through a set of 2mm to 200 microns meshes in order to collect malacofauna and wood charcoal.

This long-term hand-excavation, impossible to implement as such in a development-led archaeology context, offers the advantage of allowing all the necessary observations in terms of size and shape of the mine, of stratigraphic relation with the other structures and of stratigraphical description.

In the case of Spiennes, where the layers of the surrounding substratum are varied and where the stratigraphy of the backfills is extremely complex because of the depth of the shafts, the detailed stratigraphic study proves essential in order to decode the mining activity (Fig. 9). It allows the understanding of the taphonomic history of the structure between its creation and the moment when it is excavated (natural backfilling by runoff, wall collapse, drawdown) and makes possible, as it was achieved for the Jablines and A5 highway mining sites, the reconstruction of the initial morphology of the mine as it was dug, often far removed from what is actually observable. It documents with accuracy the phases of mining activity, shutdown and resuming of the mining activity. The accumulation of such data can help answering questions about the periodicity and the intensity of mining operations and, on a broader level, to clarify step by step the issue of site occupation.

Manual excavation and dry sieving enable a very satisfying sampling of the remains preserved in the backfills of the shaft, notably bones and pottery which, a specificity of the site, are not uncommon. Remains of domestic animal foetus, evidence of cattle breeding in the close vicinity of the site, could thus be discovered (Fig. 9).

Dry sieving through a 4mm mesh is interesting for collecting the very numerous nearly contemporaneous intrusive bones found on the whole depth of the shaft (amphibians, small mammals…), the analysis of which

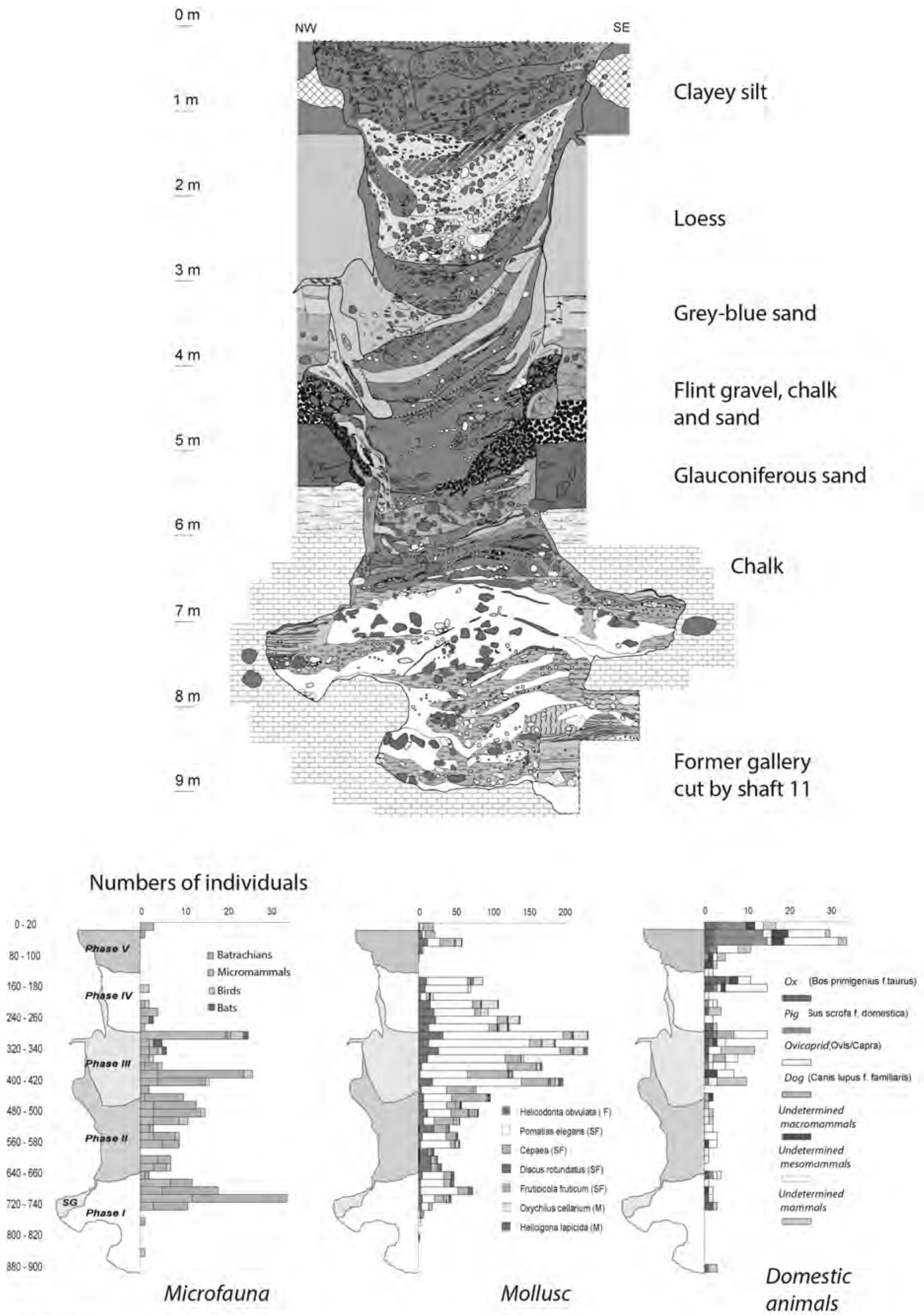

Fig. 9. Spiennes, Mons district, Belgium. Stratigraphic cross-section of the ST 11 shaft in Petit-Spiennes and its interpretation on the basis of the stratigraphy and the fauna. CAD: M. Woodbury, Public Service of Wallonia.

helps to grasp both the duration of the filling process and the environment of the mining site (Collet and Van Neer 2002).

If the occasional collecting of anthracological samples is more limited and can also provide data on the environment, it can help us understand mining techniques as well. In Spiennes as in Jablines specific tree species may have been used for lighting at the bottom of the mines (Aurélie Salavert, personal communication). The site of Spiennes turned out to be very rich in malacofauna, and the upper layers of the shafts backfills proved to be a rather good pollen trap. Cross-checking the palaeoenvironmental data gave consistent results.

Assessment of experiences: a universal method for the excavation of mining sites?

Confronting those different experiences allows to highlight a number of consensual methodological approaches for the excavation of mining sites in a development-led context. Complete topsoil stripping of the areas to be constructed seems inescapable from now on, an aspect that has to be emphasized. Indeed it is the only way to obtain an accurate overall map of the archaeological structures that gives an idea of the density of the mining site and can serve as a basis for discussing excavation plans and methods. When the development plan permits, the digging of cross sections in the substratum seems essential for the understanding of local geological contexts and flint gitology. They alone allow the assessing of local variations in the distribution of the seams and the quality of the raw material. Observations that are made on that occasion can bring elements of explanation to potential variations in the morphology of the mining structures.

The reading of stratigraphies appears as an unavoidable step, especially in the case of deep structures for which the filling process could have spread over time and thus be the result of very different events (anthropic backfillings, natural collapses, animal falls, etc.). The removal of artefacts by stratigraphic units is self-evident in order to achieve a thorough understanding of the structure, the way it was operated, the way mining activities were organized. The use of 3D recording systems can also be considered because it allows a dynamic reconstruction of the structures and, beyond the educational aspect, it can provide information about the quantities dug out and the yield rate of the mines.

The palaeoenvironmental approach of which the interest was clearly underlined in the recent research in Spiennes also has to be taken into account systematically as it conveys additional information on the evolution of the mining structures after they were abandoned in areas not immediately perceptible to archaeologists. However a sampling strategy has to be developed because the malacofauna is overabundant and the risk of duplicating redundant results is real. Anthracological and palynological approaches are more mixed because remains are often badly preserved. This does not prevent from targeting occasional eye-samplings of, for instance, wood charcoal in the mining waste deposits that could provide data on mining techniques.

In this way, as part of a development-led operation, a hand-excavation is necessary for some of the shafts. The use of the mechanical excavator can only be conceived as an addition to manual excavation and should be involved only as a second step. Mechanical excavation experiences show, indeed, the shortcomings of the methodology when it is used on its own. Confronted with the fast destruction of the site and with the weakening of the chalky bedrock, it is impossible to optimize the recording of both artefacts and structure morphology.

The use of the excavator nevertheless offers some advantages that should be emphasized. Besides reducing the duration of the operation – hand-excavation is time consuming and demanding for the field team – it provides without doubt an easy global view of the site. It also allows, and therein probably lies its main interest, to explore a large number of structures, even to excavate all the structures. This ensures that no major information is lost. Confronted with the repetitive nature of the mining structures on the same site, one could question the scientific value of exhaustiveness. When data recording conditions are good, the excavation of all the mining structures allows the drawing of a map of the mining features at the depth of the flint seams and of the galleries and shafts overlaps. This allows to measure accurately the exploitation rate of the flint seam and to evaluate the volumes of raw material extracted on a given area but also to estimate the quantity of tools produced. In this way, when time variable is taken into account, one can suggest interpretations on the evolution of the site discuss the role of the mining site within the territory occupied by Neolithic people – whether they be miners or not – and on a broader scale, the place of mining products within the Neolithic economic system. However, the two case studies of exhaustive excavations in Ri-Rônai and Mesnil-Saint-Loup were made possible only because the mining shafts were of reasonable size. One can question the efficiency and the cost of such a method if it was implemented on deep shafts such as in Jablines or in Spiennes. At all events we have shown that manual and mechanical

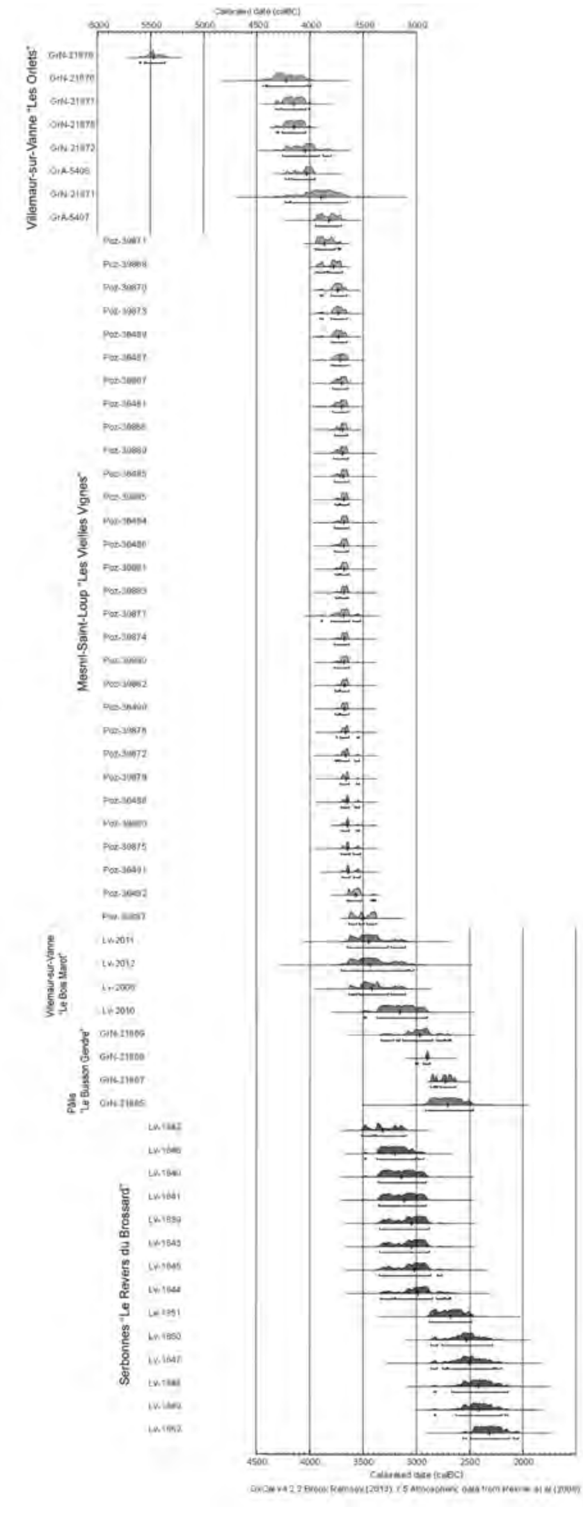

Fig. 10. Series of radiocarbon dates for the mining sites of the Pays d'Othe, Aube district. CAD: A. Hauzeur.

excavations are complementary, that flexibility should be maintained in the use of the excavator, which should never be undertaken without a close monitoring of the drawing of profiles and the recording of the data.

As was pointed out above, the general difficulty of dating mining sites was overcome when a series of radiocarbon dates were obtained. Those show the length of mining site occupation on the regional scale as was evidenced in the 'Pays d'Othe' (Fig. 10) but also show consistency within the sites themselves. However, when the clustered dates in Mesnil-Saint-Loup are compared with those of the A5 Highway one can argue that such a higher accuracy could be reflecting the fine-tuning of dating methods in the past fifteen years. The number of dates should however be in relation with the number of excavated shafts and distributed over the whole studied area. Suggesting a mining operations model by extrapolating the data (kriging) is possible if the sampling protocol of the structures to be dated is established well in advance. Selecting the samples in a rigorous way, a ratio between one in five and one in ten structures to be dated could be used.

Conclusion

By confronting various field experiences spread over more than 20 years we can offer a methodological assessment of the different excavation strategies implemented and emphasize the strong and weak points of each approach developed. The understanding of flint mines, as any other site type, necessitates a reliable recording methodology allowing a maximum use of the data. In a development-led archaeology context, a consensus is emerging on the rational use of the excavator next to manual excavations which ensures the basis of the documentation. The mechanical excavation of the totality of the mining structures can only be considered if it is undertaken with a clear scientific goal and not as a money-saving solution.

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