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Mining and Quarrying

Geological Characterisation, Knapping Processes and Distribution Networks during Pre- and Protohistoric Times

Edited by
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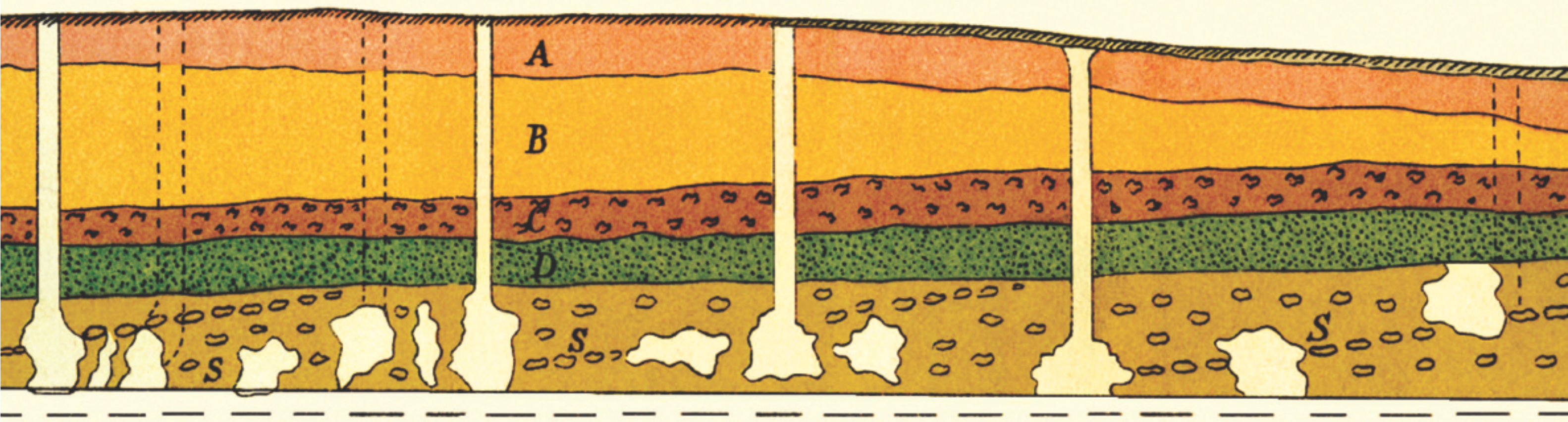

**Proceedings of the 7th International Conference of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times
Mons and Spiennes, 28th Sept. – 1st Oct. 2016**

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Dedication

We would like to dedicate this volume to the memory of Alan SAVILLE (31 December 1946 - 19 June 2016), Praesidium member of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times 2007-2016, President of the Society of Antiquaries of Scotland 2011-2013, outstanding prehistorian and lithic specialist.

Picture © Society of Antiquaries of Scotland.

Participants at the 7th Conference of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times in the Natural Sciences Museum of the Public Service of Wallonia in Mons (28th September - 1st October 2016). Picture F. Dor © SPW/TLPE.

Preamble

After the meetings of Paris (2007 and 2012), Madrid (2009), Vienna (2010), Florianopolis (2011) and Burgos (2014), it was a great pleasure for the Cultural Heritage Department of the Public Service of Wallonia (in French, *Département du Patrimoine,* renamed Walloon Heritage Agency - in French *Agence wallonne du Patrimoine* - on 1st January 2018) to welcome the 7th Conference of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times from 28th September to 1st October 2016 on the topic 'Mining and Quarrying. Geological Characterisation, Knapping Processes and Distribution Network during Pre- and Protohistoric Times'.

Professor Jacek Lech, past president of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times, had proposed holding the conference in Mons and Spiennes (Province of Hainaut, Wallonia, Belgium) several years ago when visiting the ongoing excavation at the Neolithic flint mines of Spiennes. Indeed Belgium and Wallonia had never previously hosted any Flint Symposium or the UISPP Flint Mining Commission Conference. The flint mines of Spiennes had been only the destination of an excursion during the Flint Symposium held in Bochum in 1999. The conference held in Mons and Spiennes fixed this oversight. The Cultural Heritage Department expresses its gratitude to Professor Lech for this proposal and for his deep interest in the Flint Mining site of Spiennes.

And, as a matter of fact, Spiennes and the Mons basin are perfect locations to welcome a conference on prehistoric flint mining. The basin is rich in prehistoric sites from the Palaeolithic to the Neolithic period; in flint mines from the Neolithic period, such as Mesvin 'Sans Pareil', Flénu 'l'Ostenne' and Baudour-Douvrain; and in gunflint quarries from the 19th century AD! Together with the British Neolithic flint mines, the Neolithic flint mines of Spiennes were the first prehistoric mines to be investigated, as early as the second half of the 19th century. In the 1850s the engineer and amateur archaeologist Albert Toilliez collected numerous axehead preforms at Spiennes and claimed that Spiennes was the place of a large 'axehead factory' dating from the end of Prehistory. The significance of Spiennes was also emphasised by John Evans, the famous antiquary, who visited the site in the 1850s. The profile of the Neolithic flint mines of Spiennes was raised yet further by the research conducted by Auguste Houzeau de Lehaie, Alphonse Briart and François-Léopold Cornet in 1867; by the detailed cross-section of the railway trench that was cut at this time; and by the excavation of deep shafts at Camp-à-Cayaux by Alfred de Loë in 1912–1914. The research continued throughout the 20th century. In the 1960s and the 1970s François Hubert conducted exemplary excavations of workshop places at Camp-à-Cayaux and of a Michelsberg ditched enclosure at Petit-Spiennes. This research increased the scientific interest in Spiennes. At the same time, the Royal Belgian Institute of Natural Sciences (RBINS) started investigations on the Palaeolithic in the area, revealing a succession of four alluvial terraces associated with Lower and Middle Palaeolithic industries.

During the last 20 years, the Public Service of Wallonia, *Direction de l'Archéologie* (now integrated into the *Agence wallonne du Patrimoine*), together with the City of Mons and the *Société de Recherche préhistorique en Hainaut*, invested in the protection, management, promotion and research on flint mining of the site of Spiennes. The Public Service of Wallonia proposed the site to the UNESCO World Heritage List and it was inscribed in December 2000. Since 1997, important excavations of shafts and chipping floors have been undertaken by the Archaeological Service of the Public Service of Wallonia in partnership with the Society for Prehistoric Research in Hainaut (*Société de Recherche préhistorique en Hainaut* - SRPH). These excavations have enhanced knowledge about Spiennes in various topics such as raw material procurement, mining methods, flint products, paleoenvironment and the daily life of the miners. In 2003, the Public Service of Wallonia renewed the old museum located upon the deep shafts at Camp-à-Cayaux, transforming it into a centre dedicated to archaeological research in Spiennes.

The opening, in April 2015, by the City of Mons of an Interpretive Centre dedicated to the Neolithic flint mines of Spiennes – aptly called SILEX'S – lends all the more interest and value to the site. This new cultural and educational centre was co-financed by the European Union (European Regional Development Fund), Wallonia (*Commissariat général au Tourisme* - General Commission for Tourism) and the City of Mons.

Additionally, Mons has a long-standing tradition of scholarship and research in mining engineering and geology, thanks to the Mining School, the oldest university of the City of Mons, set up in 1836. This school – now associated with the University of Mons and called the Faculty of Engineering – still has an important department of Geology and Applied Geology which collaborates in research on flint mining. Mons is therefore the perfect place to share the experiences of archaeologists and geologists around a common interest: prehistoric flint mining.

The conference took place in the Regional Museum of Natural Sciences, a museum created as early as the 1830s, initially linked with the City of Mons and the School of Engineering. This Museum is now an education centre for sciences attached to the Direction of Agriculture, Natural Resources and Environment of the Public Service of Wallonia.

Finally, we especially thank the institutions who cooperated in the organisation of the conference and the publication of the proceedings: the UISPP Commission on Flint Mining, the 'Events Unit' attached to the DGO4 of the Public Service of Wallonia (*Direction générale de l'Aménagement du Territoire, du Logement, du Patrimoine et de l'Energie*), the Society for Prehistoric Research in Hainaut, the Natural Sciences Museum of the SPW in Mons (*Musée des Sciences naturelles du SPW*), the Museums of the City of Mons (Pôle muséal de la Ville de Mons), the Educational Service for the Promotion of Sciences at the University of Mons (SciTech2), the Association for the Diffusion of Information in Archaeology (*Association pour la Diffusion de l'Information archéologique*, ADIA), the Belgian Society for Anthropology and Prehistory (*Société royale belge d'Anthropologie et de Préhistoire*, SRBAP) and the Royal Belgian Institute of Natural Sciences in Brussels (*Institut royal des Sciences naturelles de Belgique*, IRSNB). We also thank all the Cultural Heritage employees and volunteers who gave their time to ensure the success of the meeting.

Jean PLUMIER
Inspecteur général
Agence wallonne du Patrimoine
Service public de Wallonie
General Inspector
Walloon Heritage Agency
Public Service of Wallonia

Preface

The 7th Conference of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times took place in Belgium, near Mons, Hainaut, over four days from the 28th of September to the 1st of October 2016, on the invitation of the Public Service of Wallonia and the Mons town museums. The decision to hold the meeting at Mons was largely guided by the presence of the Spiennes mine, well known internationally both through its UNESCO World Heritage status and through the excellence of research undertaken there. Paradoxically, the commission had never been to Spiennes since its creation in 2006, despite the fact that the sites of Spiennes 'Camp-à-Cayaux' and 'Petit-Spiennes' offer numerous opportunities for visiting extraction features, as well as providing high quality data that has constantly been renewed to keep up with developments in Neolithic mining research. Thus this significant local potential facilitated the organisation of the meeting in two phases, the first with presentations of papers and discussions between participants (two days), the second with excursions (two days). Altogether, the conference brought together eighty researchers, from fourteen European countries as well as the United States.

The scientific committee chose three themes for the conference: mining and quarrying, geological characterisation, knapping processes and distribution networks during pre- and protohistoric times. Altogether, nineteen papers were given, together with ten shorter presentations in the form of posters, unequally spread across the three themes. The first theme brought together seven papers and three posters. In addition to the results of recent research on various prehistoric mining sites in France, in the Vaucluse (DE LABRIFFE & REGGIO, this volume) or in Champagne (MARTINEAU *et al.*, this volume), in Catalonia, in Cantabria and in Hungary (BIRÓ *et al.*, this volume), methodological presentations were given dealing with aspects such as defining the extent of sites with non destructive methods like Airborne Laser Scanning (BUDZISZEWSKI *et al.*, this volume) or geophysical survey (BACZKOWSKI, this volume). The mapping of raw material outcrops (VALDE-NOWAK & KERDENER-GUBAŁA, this volume) or of production waste, as around the mine at Rijckholt-St. Geertruid (Netherlands), is another approach to the extent of sites. The creation of databases on a type of raw material, in this case Krzemionki Banded Flint, provided the opportunity to comprehend problems involved in managing large quantities of data of diverse origin and nature.

The second theme was addressed by three papers and one poster. The impact of geological constraints was examined for outcrops of Cambrian and Ordovician levels in the State of New York (LAPORTA *et al.*, this volume), while the consideration of processes of change in siliceous materials now enables a reassessment of procurement territories for the various materials used on archaeological sites. Two French research projects were presented, one on the Massif Central (DELVIGNE *et al.*, this volume), the other on the Bergerac area (FERNANDES *et al.*, this volume). The contributions and limits of the PIXE analysis method on Pyrenean materials were presented in the form of a poster.

The third theme, on knapping methods and product diffusion networks, was addressed by nine papers and one poster. The presence of knapping workshops dating to the Bronze Age on the Wierzbica 'Zele' mine was documented by recent excavation (LECH & WERRA, this volume), while the question of the transmission of know-how was raised through study of blade production on the Casa Montero mine, Spain (CASTAÑEDA *et al.*, this volume). The complexity of distribution networks of good quality raw materials was illustrated by various examples for Ghlin flint from Belgium (DENIS, this volume), Cinglais flint from Normandy (CHARRAUD, this volume), Balkan flint, materials from the Gargano region across the Adriatic sea, flints from Salinelles (Gard, France), as well as materials from the Mons region across Belgium and northern France.

However, the sitting of this conference at Mons was also the chance to present other aspects of local research, such as the human remains from extraction features at Spiennes (TOUSSAINT *et al.*, this volume), or the extraction of local flint in the historic period for gunflint (HAUZEUR *et al.*, this volume). Also, an inventory of collections housed in the Brussels Royal Museum of Art and History revealed just how much material comes from the site of Spiennes itself (CLAES & GHESQUIÈRE, this volume), while other aspects of the collections of the Royal Belgian Institute of Natural Sciences were discussed, such as a collection of gunflints from Brandon, England or a polished jadeitite axe (ERRERA *et al.*, this volume).

Participants were also able to attend two lectures, one given at the conference by P. Topping on the social context of prehistoric flint and stone extraction in the United Kingdom (TOPPING, this volume); the other, for the general public, by J. Pelegrin at Mons University on the question of the production and diffusion of large flint blades in Europe.

The second part of the conference was taken up by the excursions, lasting just under two days. First of all, a joint visit to the Harmignies quarry was organised, enabling participants to observe the geological sections and the different layers of flint contained within the Spiennes Campanian chalk and exploited in the various mine shafts. Participants were then split into three groups for the three visits planned. As the mine shafts could only be visited by small groups of twelve people at the most, and in order to allow enough time for the sites to be fully appreciated by all, a rotating system of visits was organised, with each group staying half a day at each site. Thus all the conference participants were able to visit successively the deepest shafts (16 m) on the Spiennes 'Camp à Cayaux' site, exceptionally opened for the occasion, the excavation underway on shaft ST6 at 'Petit-Spiennes' and the visitor centre at ‘Petit-Spiennes’ with its permanent exhibition, as well as a shaft previously excavated by the Society for Prehistoric Research in Hainaut (SRPH).

This 7th Conference of the Commission was thus very rich and well-appreciated by the participants. The publication of the proceedings, thanks to the efforts of the contributors as well as the organisers, all of whom must be warmly thanked here, is a further token of the success of the event and of the dynamic strength of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times.

(translation M. Ilett)

Françoise BOSTYN
President of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times
Présidente de la Commission Mines de Silex pré- et protohistoriques de l’UISPP

Anthropologica et Præhistorica, 128/2017 (2019) : 13-30

Methodologies of extraction: The mining techniques in the Early Neolithic flint mines of Southern England and their continental origins

Jon Edward BACZKOWSKI

Abstract

Recent research on the chronology of the Early Neolithic (4000-3500 BC) in Southern England has shown that flint mines are amongst the earliest monuments to appear in the landscape. This paper will outline the findings from research into extraction methodologies at the mines of Southern England. It is proposed that these methods are also observable in the flint mines of Northwest Europe. It is also argued that at present there is no evidence of a chronological development from proto-mines to deep flint mines in Southern England. To support this hypothesis the unpublished excavation of the only known Neolithic drift mines in Southern England, on Harrow Hill, West Sussex, will be investigated. Finally, a review of the radiocarbon dates of Southern English flint mines is undertaken, which places these significant monuments into a chronological model and further demonstrates a link to their continental counterparts.

Keywords: Extraction, methodology, Neolithic, chronology, drift mines, Southern England, deep mines.

Résumé

Les recherches récentes sur la chronologie du Néolithique ancien (4000-3500 BC) du sud de l'Angleterre ont montré que les mines de silex figurent parmi les plus anciens monuments apparaissant dans le paysage. Cet article entend donner un aperçu du résultat des recherches menées sur les modes d'extraction mis en œuvre dans les minières du sud de l'Angleterre. Nous faisons la proposition que ces méthodes sont aussi présentes dans les mines de silex du nord-ouest de l'Europe. D'autre part, à l'heure actuelle, aucun indice ne permet d'envisager une évolution chronologique depuis les proto-mines vers les mines profondes en Angleterre du Sud. La fouille non encore publiée de la seule mine néolithique par fonçage horizontal d'Angleterre du Sud, à Harrow Hill dans le Sussex, sera examinée en appui à cette hypothèse. Enfin, un bilan des dates radiocarbone des mines d'Angleterre du Sud est proposé, pour placer ces monuments au sein d'un modèle chronologique et achever de démontrer le lien qui les unit à leurs homologues continentaux.

***Mots-clés** : extraction, méthodologie, Néolithique, chronologie, mine par fonçage horizontal, Angleterre du Sud, mines profondes.*

1. INTRODUCTION

In a 2014 article (BACZKOWSKI, 2014) I proposed that the Early Neolithic flint mines of Southern England show clear connections with continental mines. This was based on the observation that a shared extraction methodology can be identified at deep mine complexes across Northwest Europe. It was further suggested that the early dates for the beginning of shaft and gallery flint mining in Southern England, around the 40th century BC, are so close to those of the Northwest European sites that there could be no time for a methodology to have developed coaxially and independently on either side of the Channel.

A central point of the original hypotheses is that there is no evidence of a chronological development at the Southern English mines from simple extraction techniques, such as quarrying, to the more advanced method of deep mining. The purpose of the paper is not to repeat the findings of the 2014 article in full, but rather advances this hypothesis with a case study of one of the most recent excavations of a flint mine in Sussex, where simple drift mines were discovered. The paper will conclude with a brief reconsideration of the chronology of deep extraction in the region. It will be hypothesised that, at present, there is no evidence for earlier, basic forms of extraction at the Sussex sites, further supporting its introduction from the Continent.

2. SOUTHERN ENGLISH MINES

In Southern England there are currently nine confirmed Early Neolithic flint mines (BARBER *et al.,* 1999), broken into three groups by their geographical location. The Worthing Group, West Sussex, comprising of mines at Blackpatch, Church Hill, Cissbury Hill and Harrow Hill, the Chichester Group, West Sussex, with mines at Long Down and Stoke Down, and finally the Wessex Group, with mines at Martin's Clump, Hampshire, and Easton Down (Fig. 1). The objective at all the Southern English mines was to win flint for the manufacture of bifacially flaked axes, which were often polished and distributed across the region (SIEVEKING *et al.*, 1972; GARDINER, 1990).

The Southern mines can be further divided by the observation that subtly different mining methods were employed at each group. For example, the Worthing Group mines are most associated with deep and wide shafts, such as those recorded at Cissbury that measured up to 20 m in diameter and 12 m in depth, and connected to a complex basal system of galleries (BARBER *et al.,* 1999; RUSSELL, 2001). In contrast, the Chichester Group and Wessex Group mines appear to have been based on a subtly different method of extraction, using shallow shafts with short galleries, or adits, as found at Easton Down (STONE, 1935) and Stoke Down (RIDE & JAMES, 1989).

Caution must be expressed in categorising the extraction methodology by location, as the Chichester and Wessex mines have not been excavated to the same degree as the Sussex mines and there is subsequently less information on the form of the subterranean workings. Nonetheless, the small amount of excavation at the Chichester and Wessex mines (see BARBER *et al.,* 1999), together with surveys of the surface remains (BARBER *et al.,* 1999; BARBER, 2014), indicates that large deep shafts with long galleries are likely to be more typical of the Worthing Group mines.

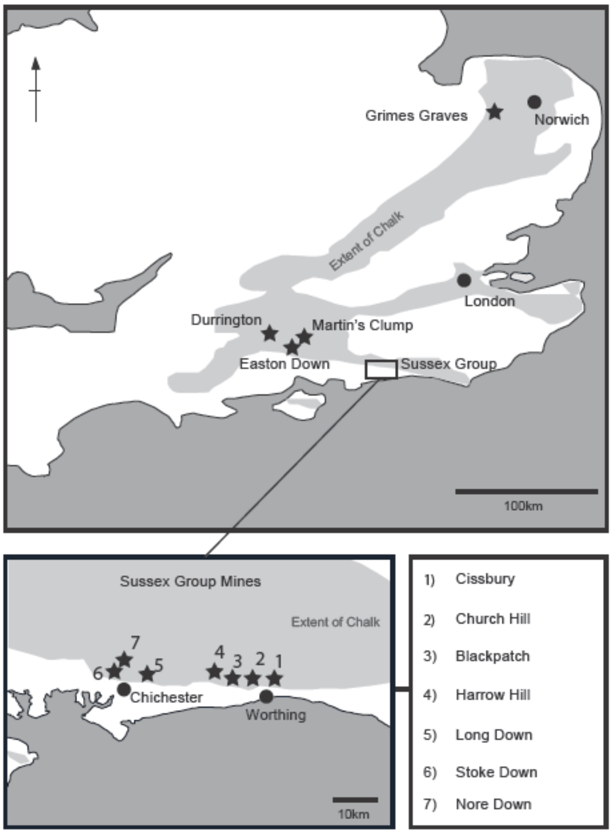


Fig. 1 – Distribution of English flint mines. Drawing: J. Baczkowski.

2.1. The dating of Southern English mines

The majority of the radiocarbon dates for the Southern English mines are obtained from red deer (*Cervus elaphus*) antler, fashioned into picks and implements for use in mining, and excavated directly from within mine workings (BARBER *et al.,* 1999). They represent short-lived radiocarbon samples from secure contexts. However, they only date individual mining events, which combined with their paucity, makes forming a precise chronology of mining in Southern England difficult.

Overall, the dates obtained from the nine Southern English mines indicate extraction activity begun shortly before 4000 BC, and ceased around 3500 BC (Fig. 2). The only other major flint mine complex in the southern half of England is located at Grimes Graves, Norfolk, and is dated to the Late Neolithic (3000-2500 BC) and Early Bronze Age (2500-1500 BC) periods

(HEALY *et al.*, 2014). The Southern English mines are therefore confined to the chalk downland and are a distinctly Early Neolithic phenomenon.

3. THE ARRIVAL OF THE EARLY NEOLITHIC AND MINING

In Sussex, as across the rest of the British Isles, the start of Neolithic has long been denoted by the arrival of new cultural material and practices from the Continent, such as Carinated Bowl pottery, polished axes and flint mining (WHITTLE *et al.*, 2011; SHERIDAN, 2010, 2011; THOMAS, 2004, 2007, 2008, 2013). From around the turn of the 40th century BC these changes announce a shift in lifestyles from 'hunting and gathering' to one based on newly adopted agricultural practices, including cereal cultivation and the husbandry of domesticated animals (ROWLEY-CONWY, 2004; COLLARD *et al.*, 2009; SCHULTING, 2013).

The early significance of the Sussex flint mines in this sequence has recently been highlighted by a radiocarbon dating program conducted on the Neolithic causewayed enclosures of Southern Britain (WHITTLE *et al.*, 2011), demonstrating that construction of these monuments began in the late 38th century BC. This means that causewayed enclosures can no longer be associated with the earliest phase of the Neolithic (4000-3800 BC), whereas flint mines are dated to the centuries before the turn of the 4th millennium BC (4100-4000 BC). Therefore, mines can no longer be thought of as peripheral to traditional Early Neolithic monuments, such as causewayed enclosures and long barrows, an interpretation that has long been advanced (BRADLEY & EDMONDS, 1993; EDMONDS, 1995; DREWETT, 2003).

At present, in Southern England only two other monuments are contemporary with the Sussex flint mines, the Coldrum mortuary monument (HEALY, 2008; WYSOCKI *et al.,* 2013) and the White Horse Stone longhouse (ASHBEE, 1993, 1998; HAYDEN, 2007), both in Kent, and both showing a continental influence (WHITTLE *et al.,* 2011, p. 257-262). Hence, the Southern mines are isolated monuments in the Early Neolithic landscape of Southern England that can

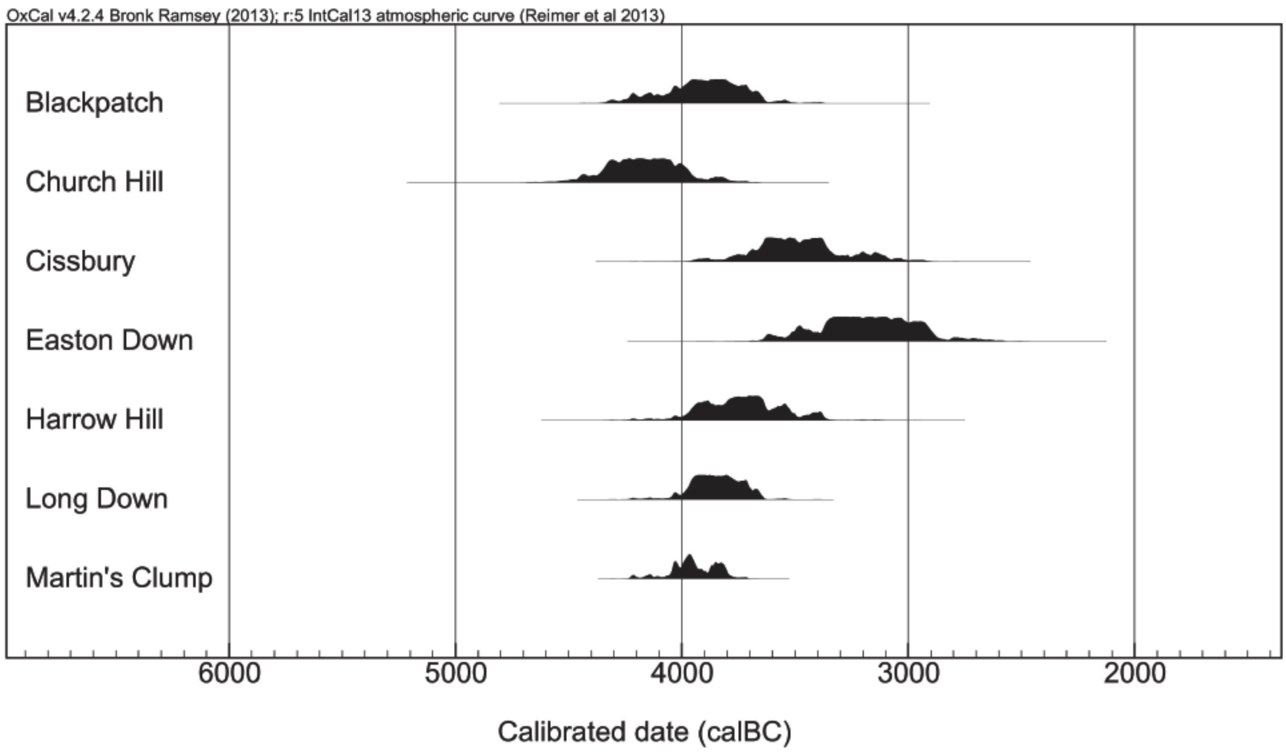


Fig. 2 – Dating of Southern English Early Neolithic flint mines.

now be considered as central to the arrival and spread of cultural practices, rather than existing on the margins of society.

As flint mines are core to the 'Neolithic Package' introduced to Southern England, it must be possible to observe a clear connection to their continental contemporaries. It is this hypothesis, a continental origin for the Southern English flint mines, which will now be discussed.

4. A COMMON METHODOLOGY?

That the Southern English flint mines share an affinity with those in Northwest Europe, particularly in France and Belgium has long been noted, since the early excavations led by 19th century antiquarians, including A. Lane Fox (later Pitt-Rivers), who noted the similarities between the Cissbury mines and those at Spiennes (LANE FOX, 1876).

It is now widely recognised that Southern English flint mining originated in the Northwestern European mine complexes, where a long tradition of deep extraction was practiced (CUNLIFFE, 2008; WHEELER, 2008, 2011; WHITTLE *et al.*, 2011), although little research has been carried out to explore this connection. Recently, parallels between the Southern English and continental mines have been noted, mostly on the mining methods, the production of axes and on a shared ideological motivation for deep mining (WHEELER, 2008, 2011). This narrative of connectivity was the basis of new research (BACZKOWSKI, 2014), when it was decided to investigate the mine workings of six sites, three in Southern England and three on the Continent, with an objective of identifying a common mining methodology.

The selection process for the sites was strict, the mines had to be well recorded, with the structures excavated both on the surface and beneath the ground. The selected English sites belonged to the Worthing Group mines, close to the West Sussex coast. The first site was at Cissbury, where a large complex of up to 300 mineshafts had been subjected to major periods of excavation from the 1870s (LANE FOX, 1876; HARRISON, 1877a, b, 1878) until the 1950s (PULL, 1956; RUSSELL 2001, p. 170-190). The second Sussex site was Church Hill, close to Cissbury and consisting of a small mine complex of around 34 mine shafts, excavated intermittently between 1932-52 (PULL, 1933a, b, c, d, 1956; RUSSELL, 2001, p. 85-158). The last site chosen was Harrow Hill, a complex of up to 250 mines, which not only has been the subject of historic excavations by the Curwen's (1926, 1937) but has also been investigated in recent times (MCNABB *et al.*, 1996; BACZKOWSKI & HOLGATE, 2017).

With regards to the continental sites it was decided not to venture far from the Channel, as it was believed a shared methodology would be best observed in mines geographically closest to the British sites (Fig. 3). The first site selected was the extensive mine complex at Spiennes, Hainaut Province, Belgium, composed of between 10,000 to 20,000 mineshafts (COLLET *et al.*, 2008, 2016) and almost continuously excavated from the late 19th century through to the present day (HUBERT, 1978; COLLET *et al.,* 2008, 2016). The second continental site examined was Jablines, Seine-et-Marne, France, where a mine complex of nearly 800 mineshafts was excavated in advance of a high-speed rail-link in 1989 (BOSTYN & LANCHON, 1992, 1995). The last continental site chosen was at Rijckholt-St. Geertruid, Limburg, the Netherlands, where a complex of around 2000 shafts had been excavated from between

Fig. 3 – Distribution of flint mines in Northwest Europe. Drawing: J. Baczkowski.

1964 to 1972 (FELDER, 1981; FELDER *et al.*, 1998; DE GROOTH, 1998).

4.1. Category of mines

While researching the mining methods employed at the six sites it was noted that although there was a variety of mine designs present, it was still possible to identify three core extraction features at all of the mines, which can be divided into the following categories,

Class 1 mines, shallow pits under 1.5 m in depth, including adits, open cast mines and drift mines,

Class 2 mines, shafts without galleries (any pit over 1.5 m of depth is classified as a shaft),

Class 3 mines, shafts that link to basal galleries.

After applying these categories to the mine complexes it was possible to identify patterns between mine complexes and understand the differing function of each feature.

4.2. Class 1 mines

Where Class 1 mines are recorded they mostly took the form of either short galleries cut horizontally into inclines to chase outcropping flint seams, or shallow pits. Of the English mines, Class 1 mines were only recorded on Harrow Hill and took the form of drift mines located close to the main deep mine complex and excavated by R. Holgate in 1986 (see below). There were also some pits on Harrow Hill, excavated by the Curwen's (1926) in the main area of deep mining. Similar features were also excavated in the 1982 excavations, and were interpreted as open cast mines, or test pits, the latter of which may have preceded the sinking of a deep, Class 3 shaft (MCNABB *et al.*, 1996, p. 24-25).

Of the continental mines, Class 1 mines have been recorded at Spiennes and Jablines. No Class 1 mines were identified at Rijckholt, although only the deep gallery system was excavated. At Spiennes, Class 1 mines included short galleries cut horizontally into the escarpment alongside the River Trouille (COLLET *et al.,* 2008, 2016). The quarries are similar in form to shallow pits discovered along the edge of the Petit-Spiennes and Camp-à-Cayaux plateaus. Although all of these features proved difficult to date (COLLET *et al.,* 2016), they nonetheless record evidence of basic extraction methods occurring close to deep mining.

At Jablines, a number of Class 1 extraction features were grouped at the northern edge of the mining field. These were shallow pits, up to 1.5 m in depth, which exploited the upper flint seams and did short develop galleries or adits (BOSTYN & LANCHON, 1992, 1995).

4.3. Class 2 mines

Of the English mines, Class 2 mines were recorded at Church Hill and Harrow Hill. On Church Hill these including one shaft, Pit A, measuring 2.2 m in diameter and with a depth of 2.5 m (RUSSELL, 2001, p. 85-158), from which no attempts to develop any galleries had occurred. A second mine on Church Hill, Shaft 2, reached a diameter of 2.4 m and a depth of 3.1 m, no galleries were developed from this shaft and again only floor flint was excavated (RUSSELL, 2001, p. 94). It was argued that these shafts never formed galleries because the miners detected previous mine workings and halted their sinking (RUSSELL, 2001, p. 87-94).

On Harrow Hill, simple 'satellite shafts' were found within the main area of deep mining. These often seemed to be abandoned before reaching the desired deep flint seams, the 3rd and 4th, either because they were placed where the chalk bedrock naturally faulted, or where earlier mine workings were detected (MCNABB *et al.*, 1996).

Of the continental sites, Class 2 mines were identified at Spiennes in the Petit-Spiennes railway cutting and along the edge of Camp-à-Cayaux, which comprised of simple shafts up to 3 m of depth (COLLET *et al.,* 2008, 2016).

At Jablines bell shaped mines were recorded in the northern area of the mine complex, ranging from between 1 m to 2 m of depth (BOSTYN & LANCHON, 1992, 1995). Depth wise these could be categorised as Class 1 mines, but because they were formed by extracting flint in all directions they can be classified as Class 2 mines, as they show a developed mining approach beyond simple open cast, or drift mining.

4.4. Class 3 mines

Deep vertical shafts joining to galleries were recorded at all of the studied sites and ranged in depth from between 2 m to 16 m. Several variations of this design do occur, and it is worth discussing these. For example at Spiennes, the shafts remain narrow, 1 m to 2.5 m in diameter, but the galleries developed in tall large rooms up to 2 m high (COLLET *et al.*, 2008). At the English sites the shafts are much wider, with diameters ranging from between 5 m to 10 m, including one example, the Large Pit at Cissbury (Fig. 4), with a diameter of 20 m and a depth of 12.8 m (LANE FOX, 1876; HARRISON, 1878; RUSSELL, 2000, p. 65).

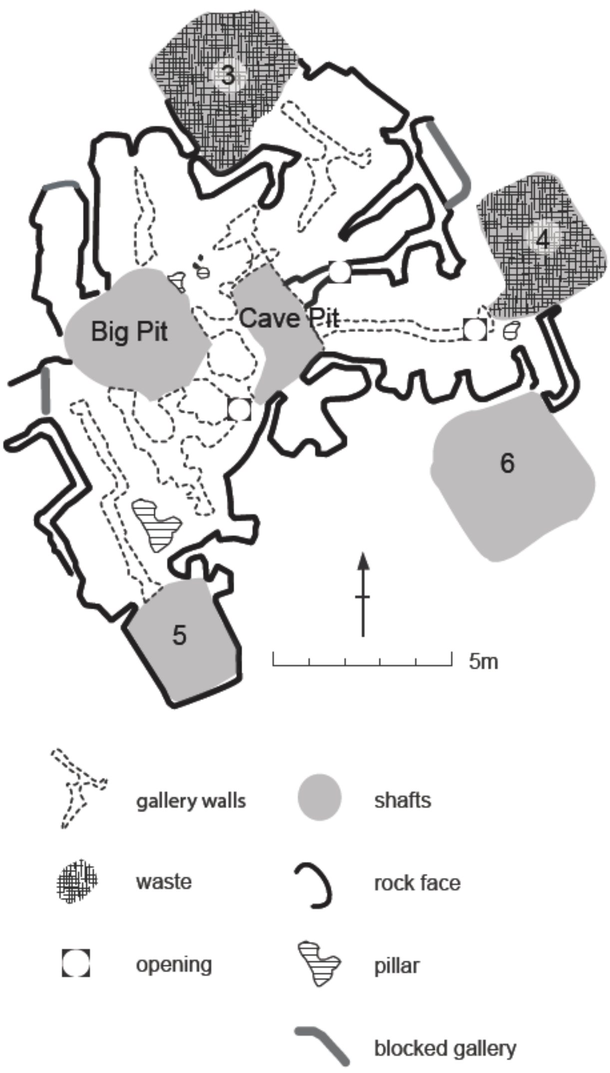


Fig. 4 – Plan of Cissbury basal system (adapted from BARBER *et al.*, 1999, p. 50, fig. 4.16c).

These differences can be mostly explained by geological factors between the sites, with miners adapting to the bedrock conditions. For example, at Spiennes and Rijckholt the upper sections of the shafts are sunk through unstable deposits and are therefore kept narrow, often less than 1 m in diameter. The small diameter may have also allowed wooden props to be added, as postulated by the excavators of Rijckholt who discovered voids that possibly indicated the presence of split timbers (FELDER *et al.*, 1998, p. 39). In contrast, the chalk bedrock in Sussex is close to the surface and extremely stable, allowing miners to excavate wide shafts and permitting as much light and air as possible to penetrate and circulate around the basal system.

Galleries on other hand uniformly remain small at most of the English and the continental mines, often only 0.6 m in height, as miners were economic and concentrated on the flints seams. Similar sized galleries existed at both Rijckholt and Jablines (Fig. 5). However, galleries at Petit-Spiennes were large, due to the size of the flint nodules being extracted and also because two seams were removed successively, resulting in galleries up to 2 m in height (COLLET *et al.*, 2008, 2016).

The principal extraction method at all sites was the use of Class 3 shafts to reach a basal system and exploit flint from deep seams. Variation, often dictated by geological factors, does exist in Class 3 mines. However, Class 1 and Class 2 mines can also be attributed to simpler extraction techniques, such as quarries or drift mines, or are produced by deep extraction practices, such as test or aborted shafts. Both Class 1 and Class 2 mines are therefore not direct evidence of a shared practice, as they are not representative of a developed methodology.

5. THE PRINCIPLE MINING METHOD

Fundamental to the deep mining methodology, observable at all deep mine complexes, is a technique known as pillar and room mining (ADLER & THOMPSON, 1992). Core to this method is the development of extraction galleries with pillars and walls left *in situ* to support the weight of the overburden, in this case

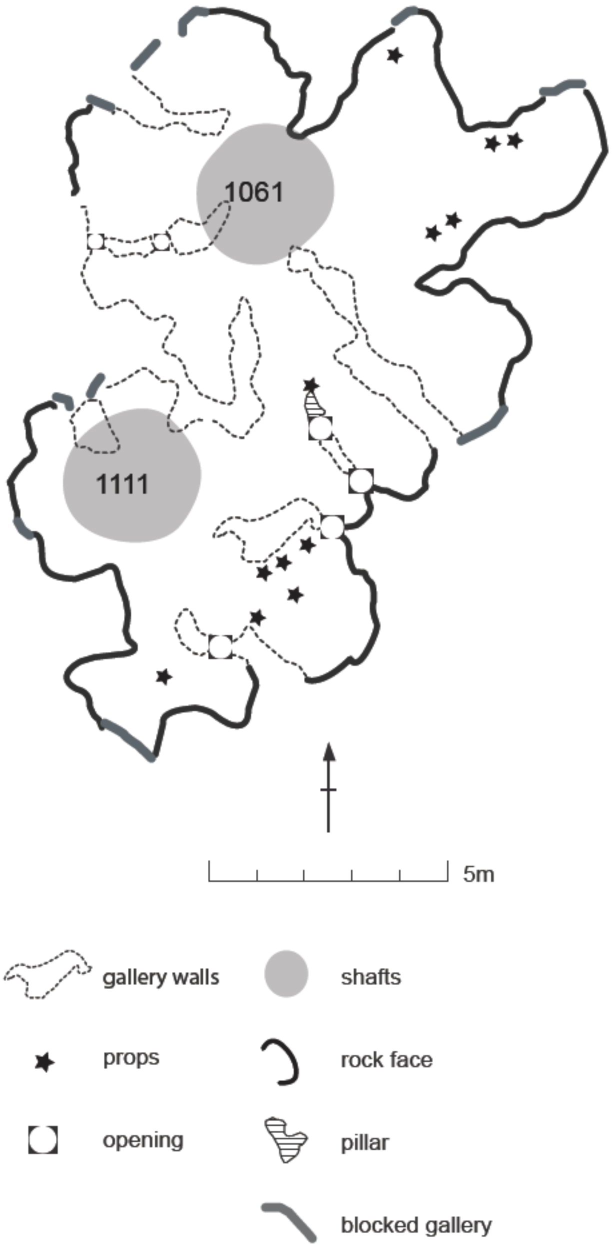


Fig. 5 – Plan of Jablines basal system (adapted from BOSTYN & LANCHON, 1992, p, 86, fig. 70).

the gallery roof. Not only does this protect the basal area against collapse, but also allows the maximum amount of material to be extracted by developing large, stable galleries.

The pairing of mineshafts is also a phenomenon observed at many mines, particularly at Harrow Hill (MCNABB *et al.*, 1996) and Spiennes (COLLET *et al.*, 2008, 2016). Such a method was probably necessary to allow air to circulate and ventilate around the gallery system, especially as paired shafts often seem associated with deep workings, as found at Harrow Hill and Spiennes.

Other similarities were observed in the mining method, including the insertion of windows or doorways at defined places in the basal gallery system. The purpose of these apertures remain mysterious: They may be purely functional, allowing access between the basal systems and air and light to be circulated, or they could be a safety feature, allowing escape in the event of a collapse. Alternatively, as some of the apertures were blocked intentionally, they may have a more symbolic role by controlling how an individual moves around the mines (EDMONDS, 1995, p. 65).

Another common technique, noticeable across all mines, is the systematic management of mine spoils (BACZKOWSKI, 2014). Exhausted galleries were universally filled with spoil from adjacent workings, which not only avoided the effort of transporting it to the surface, but also added further stability to the basal area.

Overall, it is clear that it is within the methodology of deep flint mining, represented by Class 3 mines, where a shared methodology can be observed. But how did this method progress and, most importantly, is there evidence of this development in any of the studied sites?

5.1. Simple to complex?

Across all the studied mines there is no clear evidence that basic forms of extraction, such as drift mining and open-cast quarrying, developed into complex deep mining. Simple quarries do exist, such as those at Spiennes, and although it is tempting to consider these as chronologically earlier than deep mining, this is unsubstantiated and they remain undated (COLLET *et al.*, 2016). No evidence of such a sequence at the Southern English mines is recorded, but if a progression did take place then it may be necessary to reinterpret deep mining as an insular development, albeit with a small amount of continental influence known to be occurring along the southern coast around the start of the 40th century BC (WHITTLE *et al.*, 2011).

The most likely candidates for finding evidence of earlier forms of extraction, and

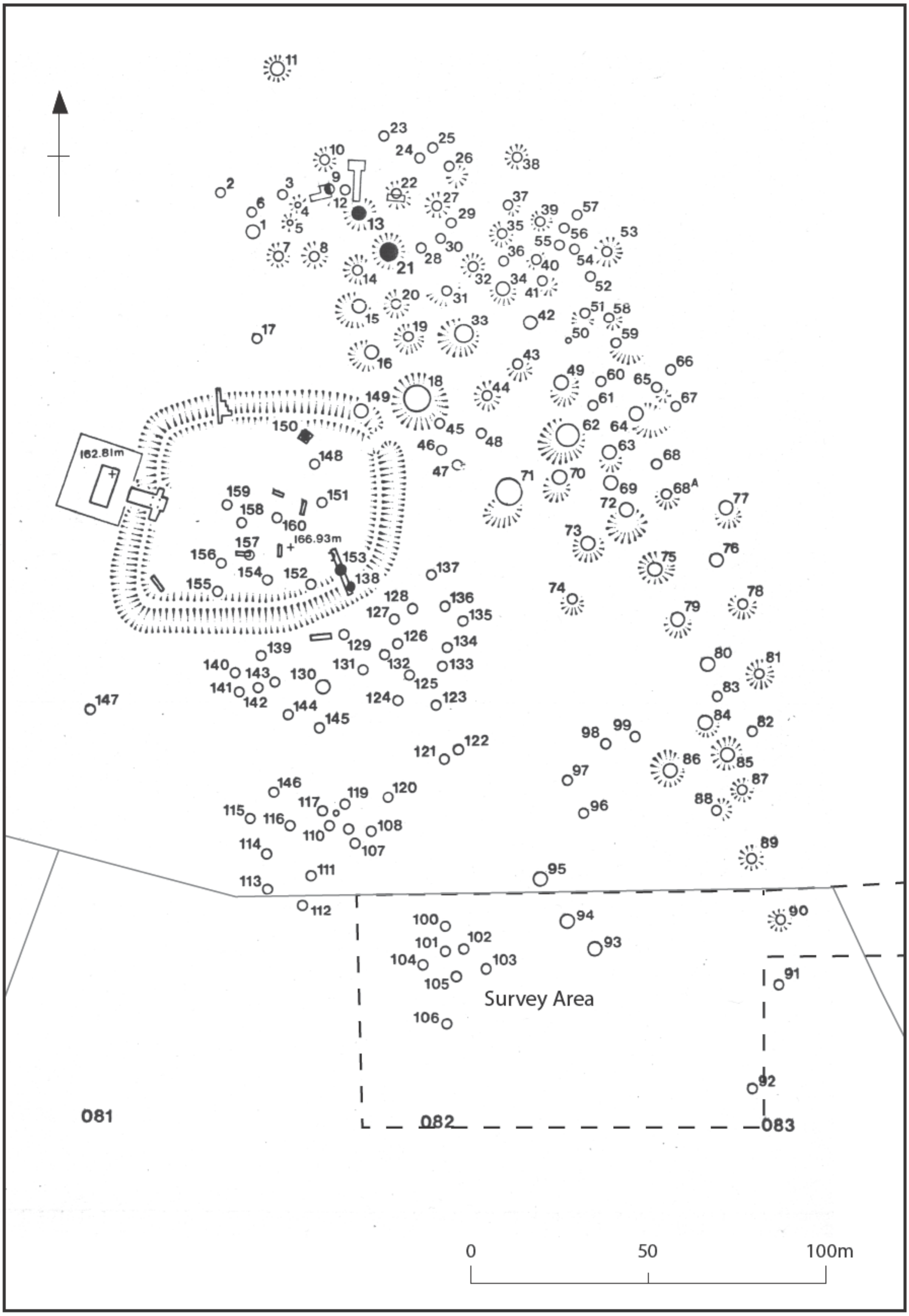


Fig. 6 – Mine workings on Harrow Hill and the survey area (adapted from a survey by F. Aldsworth).

possibly the chronological development of deep mining in Southern England, is undoubtedly the Worthing Group mines. These mines have consistently provided the earliest dates for mining in Southern England, with extraction activity beginning around the 41st century BC. It should be noted that these dates are obtained from antler picks recovered from directly within mines and therefore relate to deep shaft mining, rather than more basic forms of extraction.

A review of the excavation archives of the Worthing Group mines reveals no positive identification of simpler forms of extraction pre-dating the deep mines, possibly apart from Harrow Hill, as discussed below. Also, any simpler Class 1 and 2 mines are nearly always contemporary with episodes of deep mining.

It has been postulated that extraction may have started on Church Hill where flint naturally outcrops on a steep scarp slope (BARBER *et al.,* 1999, p. 44). Although it must be noted that J. Pull surveyed and excavated extensively outside of the main mine complex on Church Hill and found no evidence of earlier quarrying, but did record later extraction features (RUSSELL, 2001, p. 122-158).

Whether deep mining developed from earlier Mesolithic extraction methods is unknown, although, as bifacial axes are distinctly different to tranchet axes, it appears unlikely. Also, where late Mesolithic tranchet axe production in Sussex has been recorded it is focused on open-air sites, with no evidence of quarrying, such as on West Hill (BUTLER, 2001) and Bullock Down (DREWETT, 1982). Possible Mesolithic extraction pits have been recorded (CARE, 1982), but these hardly amount to proto-deep flint mines and do not involve the use of galleries.

6. The Harrow Hill drift mines

R. Holgate excavated perhaps the best candidate for a proto-deep flint mine on Harrow Hill in 1986. The drift mines were located south of the main deep mining complex and took the form of small entrances, or adits (BACZKOWSKI & HOLGATE, 2017). It is likely that the mines were topologically positioned to exploit a thin seam of nodular flint, which naturally outcropped on the eastern flank of Harrow Hill (Fig. 6). To date, they are the only Early Neolithic drift mines recorded in Southern England and are therefore of great importance, especially for improving understandings on the possible chronological development of deep mining.

6.1. Drift mine methodology

The methodology used in the drift mines was to cut small entrances horizontally into the steep slope where the flint seams were located. A small vertical face was then driven into the bedrock, from which the nodular flint was extracted until a short gallery was formed that undercut the natural slope. Two neighbouring adits were discovered in the 1986 excavation, the openings of which measured between 1 m - 2 m in width, a little over 0.8 m in height and were divided by an arch of *in situ* chalk bedrock (Fig. 7). Of the two mines, only the left hand entrance was fully excavated, which revealed a short gallery extending only 1 m into the natural slope.

It appears that the drift mines were not immediately backfilled after extraction activity ceased, as much of the mine spoil deposited into the entrances comprised of blocky chalk rubble and chalky silts that were weathered and yellow in colour (BACZKOWSKI & HOLGATE, 2017). It was also apparent that the mines were not completely closed, as a deposit of brown-orangey clay had formed between the mine waste and the short galleries. This indicates that the spoil from the working of the drift mines was moved a short distance from their entrance, before being re-deposited back into the mine at a later date (Fig. 8). However, it is unclear if the spoil from an individual mine was re-deposited back into the same entrance from which it originated, or if spoil was moved sideward along the slope into the next mine to be excavated.

6.2. Flint working

In total 1128 pieces of struck flint were recovered from the drift mines, predominantly resulting from the production of bifacially worked implements, almost certainly axes. Although a small amount of blade production was recorded, the flintwork assemblage comprised primarily of

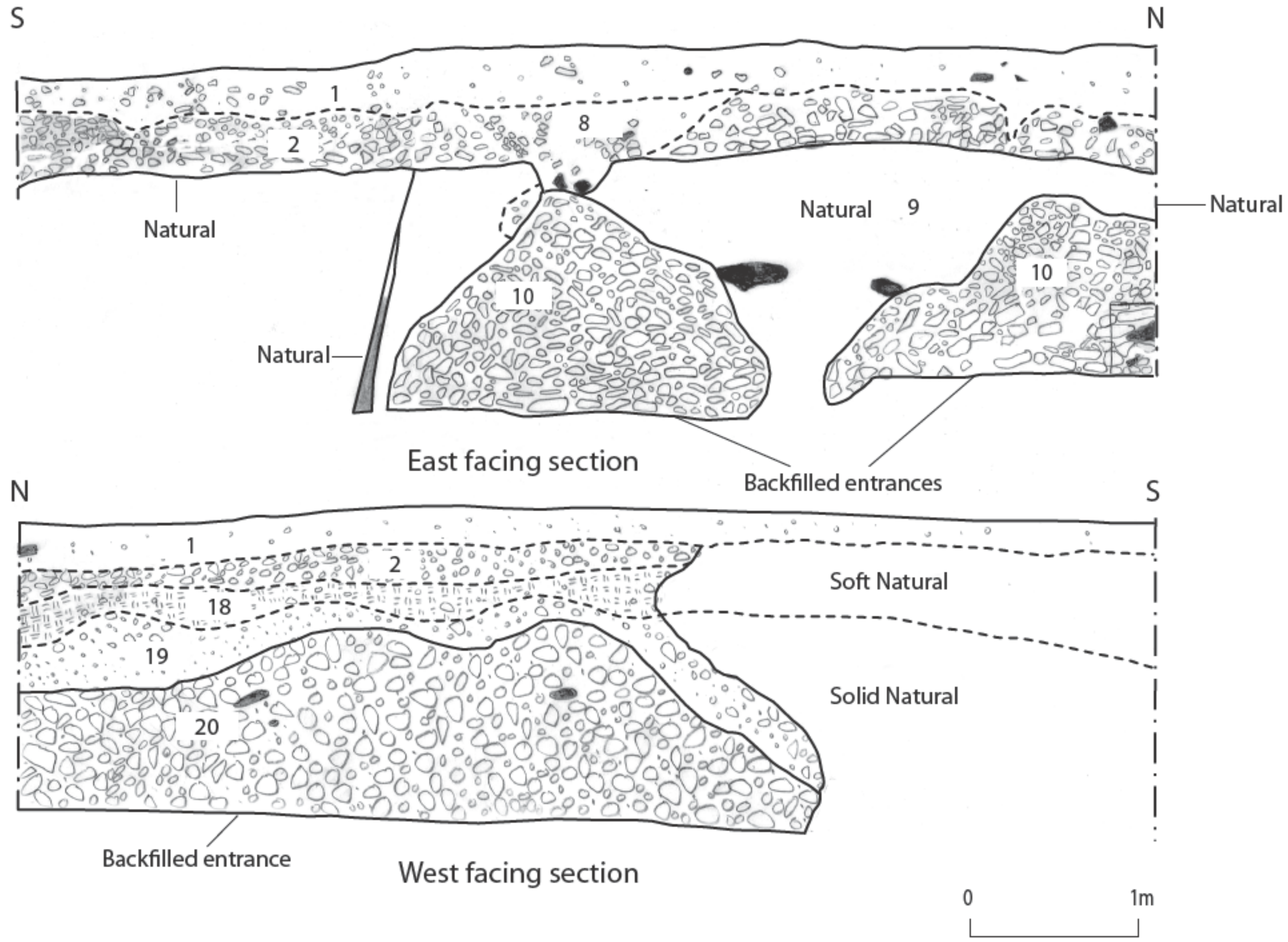


Fig. 7 – Section of Trench G showing the two drift mines
(Drawing: J. Baczkowski from original site excavation record by HOLGATE, 1986).

Fig. 8 – The blocked up entrance to a drift mine.
Picture: Holgate, from original site
excavation record by 1986.

hard-hammer and soft-hammer flakes, including 453 axe-thinning flakes. Also recovered were five roughout axes and one preform axe, demonstrating that axes were being produced on the flint extracted from the drift mines (Fig. 9).

6.3. Dating and discussion of the drift mines

The date of the Harrow Hill drifts is problematic, as no datable material, such as antler picks or charcoal, was recovered. The lithics recorded during their excavation fit into a broad Early Neolithic date range for their opening (4000-3700 BC), rather than a Late Mesolithic one, but overall there was little evidence from the drift mines to tie them into the chronology of mining on Harrow Hill.

An approximation of their date can however be drawn from their spatial relationship with the deep mines, as examination of a large flint working floor excavated by R. Holgate in 1986 reveals. This flint working area, located uphill and to the north of the drift mines, measured roughly 30 m^2 and was revealed to contain a large density of debitage, 32,135 pieces in total, resulting from the production of bifacial axes. The production floor was difficult to date, but the fact it was found uphill from the drift mines and located within the southern most area of the deep mine complex strongly infers that it was related to shaft extraction activity.

Analysis of the association of the working floor with the drift mines is revealing and shows that the working floor in places overlaps the drift mines, or respects them (BACZKOWSKI & HOLGATE, 2017, p. 21). Therefore, it seems likely that both extraction methods are broadly contemporary, as debitage resulting from the working of flint extracted from the deep mines is both stratigraphically above and associated with the area of drift mines (Fig. 10). If the drift mines were significantly earlier than the deep mines it would be expected that the large quantity of debitage and spoil produced during deep mining would have completely covered the drift mines, a process which would have been recorded during their excavation.

Although it is difficult to precisely place the drift mines in the chronology of extraction on Harrow Hill, it seems certain that it was being carried out at the same time as deep flint mining. This implies that the simpler form of extraction, drift mining, did not develop prior to deep shaft mining on Harrow Hill.

The reason for the existence of two methods within the same mine complex is unclear. The drift mines, in comparison to the deep mines, would have produced less raw flint, but they would have been quicker and easier to open. They appear to represent a more informal approach to winning flint, focused on exploiting tabular flint seams, when compared to the difficult and developed method of pillar and room mining. It may be that drift mining was carried out in conjunction with deep extraction by less skilled individuals, different social groups, or they could have been simply to supplement the amount of flint extracted from the shaft mines. They may even attest to changes in the social motivation for mining, albeit within the community that mined on Harrow Hill (EDMONDS, 1995, p. 61).

Overall, their presence on Harrow Hill is intriguing and proves that mining at certain sites in Sussex may be more diverse than just the method of deep mining, and that more than one method may have been employed during a single mining event.

7. Sussex mining chronology

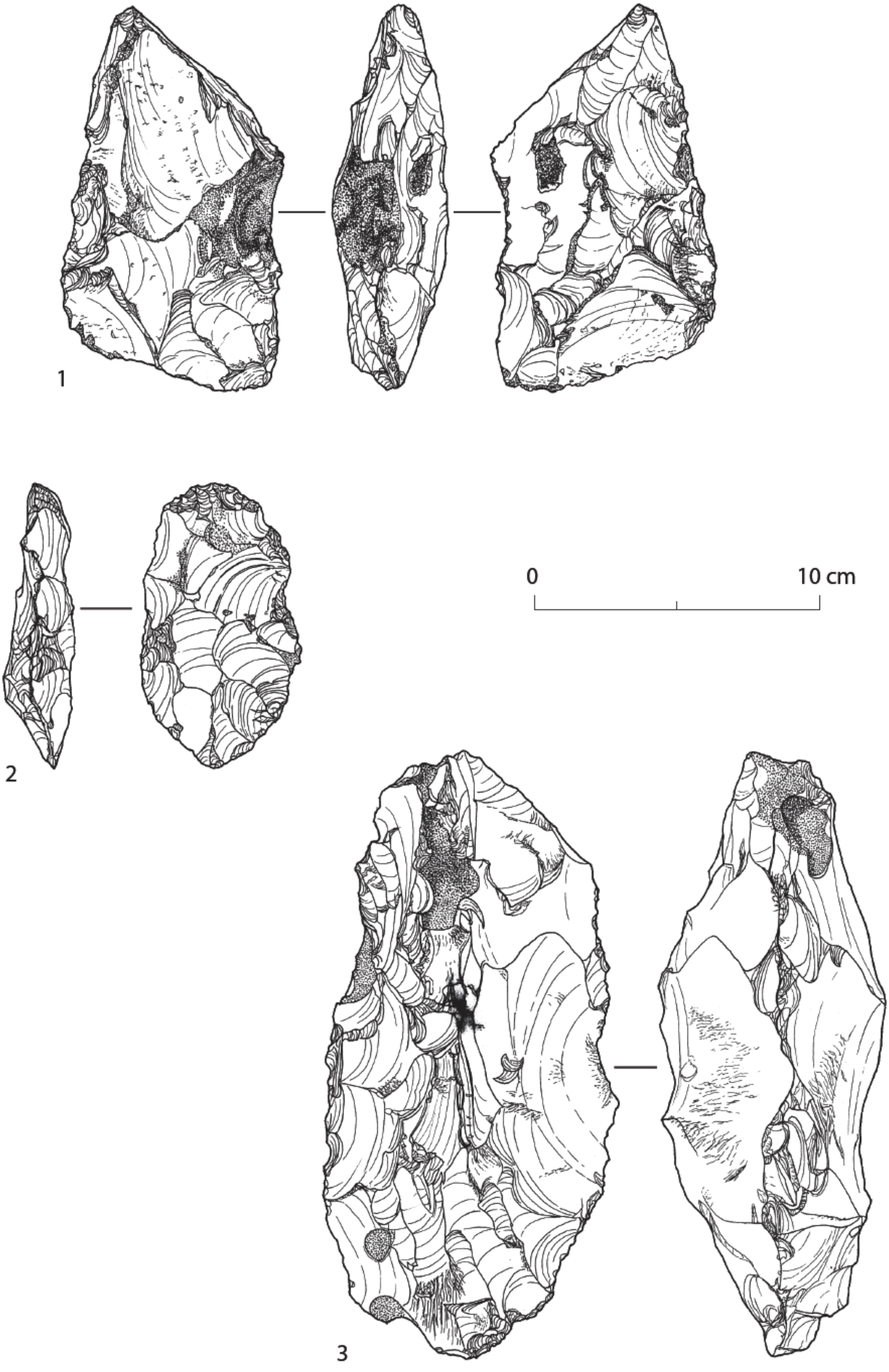
On the currently available radiocarbon dates, any attempt to define a chronology of mining is problematic, without a wider range of radiocarbon dates. However, from the dates currently available for the Southern English mines several key observations can be made that help form a brief hypothetical chronology, one which highlights some important questions on how mining may have developed and spread across Southern England.

7.1. Worthing Group mines

Of the dates obtained from the Southern English mines, the Worthing Group consistently provides the earliest (BARBER *et al.,* 1999, p. 81-82). From the Worthing Group dates, all obtained on red deer antler picks, one date from Church Hill is exceptionally early and wide in its probability range, 4490-3810 BC, and could be considered as an outlier. However, other dates, including one from Blackpatch, six from Harrow Hill and one from Cissbury all fall prior to 4000 BC at the lower date range. Therefore, mining at the Worthing Group mines possibly began around 4100 BC and was well established by 4000 BC, making them the earliest flint mines group in Southern England.

7.2. Wessex Group mines

At present, dates for the Wessex Group mines are scarce, making their chronology difficult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to understand. In consideration of the small amount of dates available, an earlier one from Easton Down with a wide calibration range, and two more recent ones obtained by Barber *et al.* from Martin's Clump, it seems likely that mining was underway by the early 40th century BC, but may have also started marginally later, at least on Easton Down. Even with a large degree of caution, with regards to postulating a mining chronology for the Wessex mines, it seems nonetheless highly probable that mining was being undertaken at the both Easton Down and Martin's Clump, between 4000-3500 BC.

7.3. Chichester Group mines

Of the Chichester Group mines, only radiocarbon dates have been obtained from Long Down. In total two were acquired during the 1984 excavation by R. Holgate, with a further five obtained recently by the author in collaboration with the ongoing project, 'Supply and demand in prehistory? Economics of Neolithic mining in NW Europe project' (EDINBOROUGH *et al.,* forthcoming). All of these radiocarbon dates were sourced from red deer antler picks collected from the upper fills of mineshafts and from working floors during J. Salisbury's excavation of Long Down in the 1950s (SALISBURY, 1961). These dates give a broad range of activity, with at least two dates demonstrating Middle to Late Neolithic activity (Fig. 11). This may be because they represent later use of the site. However, the rest of the dates strongly infer that mining was taking place later in the Early Neolithic, sometime between 3800-3400 BC. This indicates that mining at Long Down started after extraction had begun, or even waned at the Worthing Group mines, notably Harrow Hill, Church Hill and Blackpatch.

Unfortunately, no dates have been obtained for Stoke Down, but if its proximity to Long Down, rather than the Worthing Group mines is taken into consideration, then it could be proposed that it is of similar date. However, this is far from clear and at present it remains undated.

If the above chronology is taken as rough guide to the dates of the Southern English mines, it is reasonable to accept the Worthing Group mines as the earliest mine sites, with a second period of mining beginning in Chichester and possibly Wessex. In consideration of these dates it seems highly improbable that any proto-mines, and therefore a developmental phase of deep mining, may have occurred outside of Sussex. Further, it is the Worthing Group mines, where these proto-mines should exist, which are also the most excavated and best understood of the Southern English mines.

It seems then reasonable to conclude that mining in Southern England peaked between 4100-3800 BC, with a marked decrease towards 3500 BC. This is also repeated in previously obtained radiocarbon dates of the continental mines studied here and other sites (BOSTYN, 2015), with Spiennes (COLLET *et al.*, 2008), Rijckholt (FELDER *et al.*, 1998) and Jablines (BOSTYN & LANCHON, 1992) all falling within in the same 4100-3800 BC timeframe. Therefore, the peak of mining activity occurred within the same horizon in both Southern England and the Continent.

Whilst it is beyond the remit of this paper to discuss why mining appears to have intensified during this period, the dates provide yet another critical link between sites on either sides of the Channel. It is now apparent that the Southern English mines are not only connected to the continental mines by a shared method, but also by chronology.

8. Discussion

The above research has demonstrated that from the very beginning of flint mining in Southern England was based on an extraction method, pillar and room mining, which can be observed across all mines in Northwest Europe. The dates for the peak period of mining, between 4100-3800 BC, further demonstrate a clear link between Southern English and continental sites.

Fig. 9 – (opposite page) Axe roughouts from Harrow Hill.
Drawing: Reproduced by J. BACZKOWSKI 2017, original drawn by DREWETT, 1990.

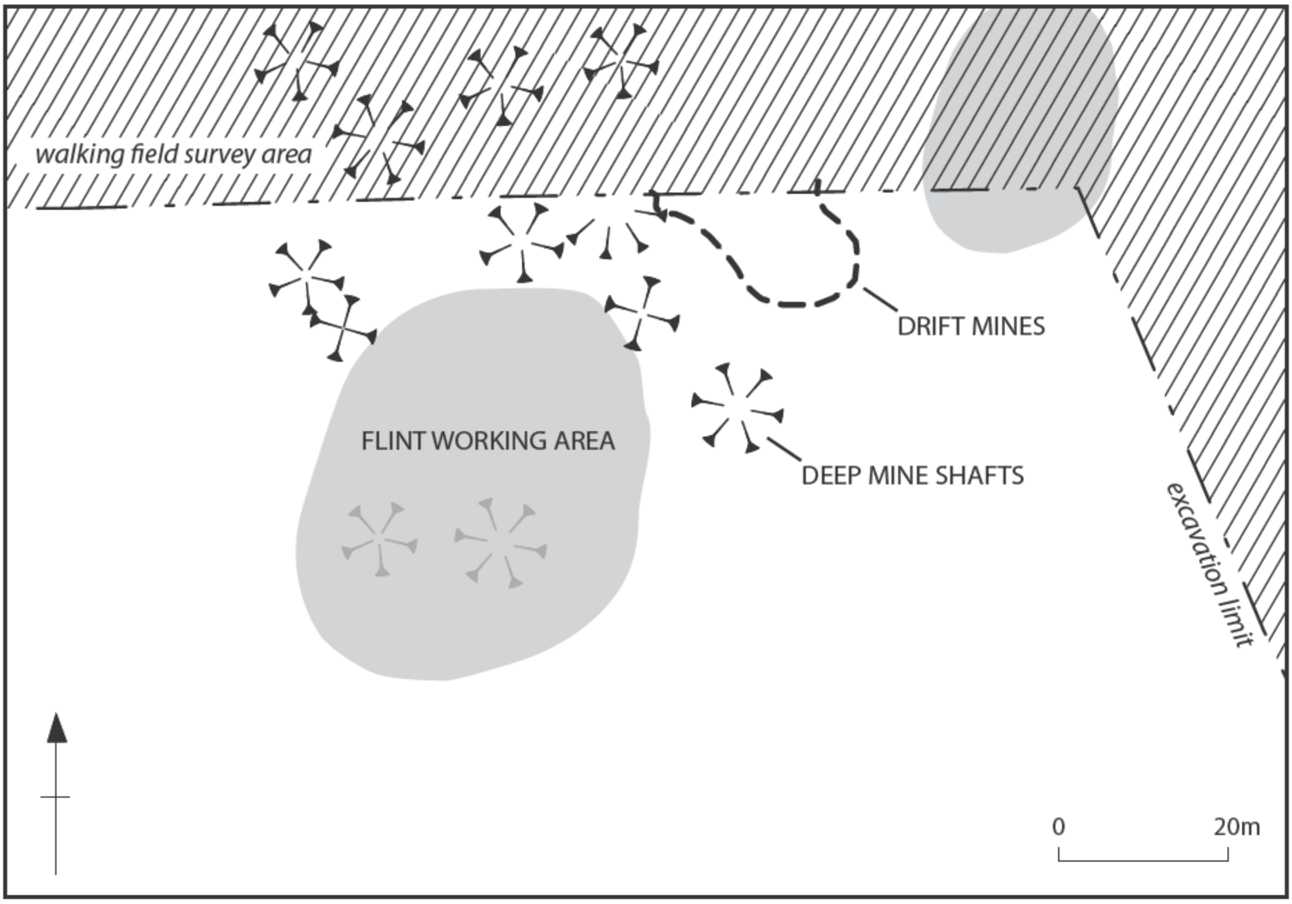

Fig. 10 – Plan of drift mines, mineshafts and working floors
(Drawing: J. Baczkowski from original excavation record by HOLGATE, 1986).

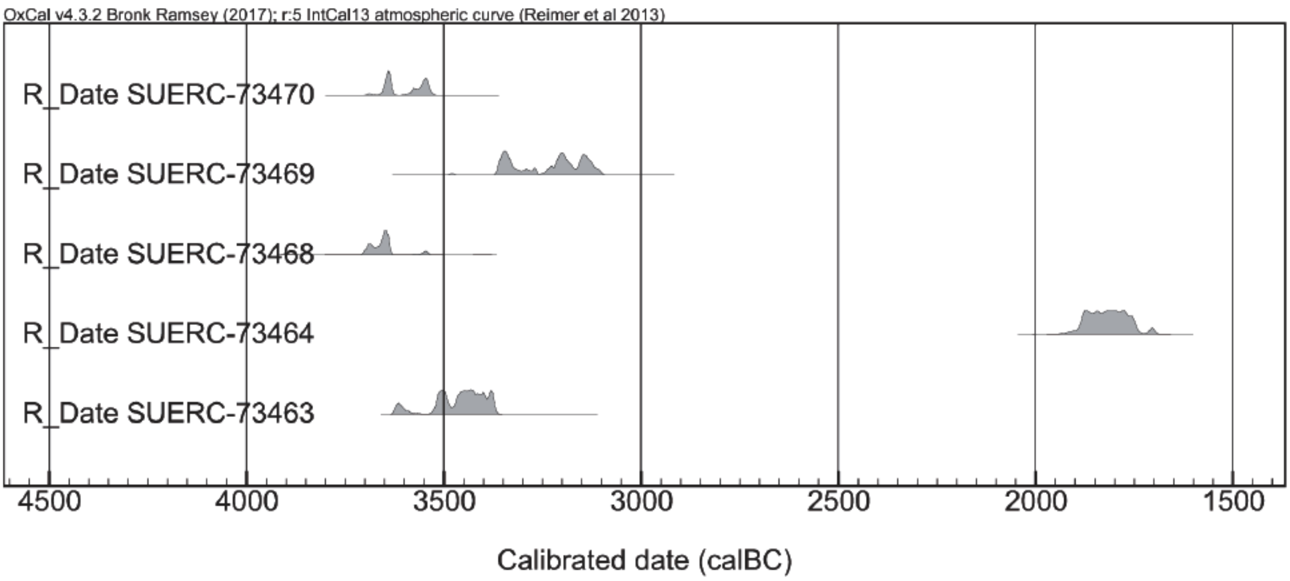

Fig. 11 – Long Down radiocarbon dates.

This finding has important implications for how the Neolithic may have spread into Southern England from the Continent, and further demonstrates the importance of mining to early communities.

Apart from the Harrow Hill drift mines there is no evidence of simpler forms of extraction at any of the Southern English sites, with the exception of Class 1 and 2 mines, which are contemporary with deep mining and mostly relate to test, or abandoned shafts. The method of pillar and room mining is most evident within the Worthing Group mines, partly because these are the best excavated, but also since they represent the most interconnected set of mine complexes. In fact, the Worthing Group mines are so close together, four mine complexes, totalling around 500 shafts in around 3 km^2, that they could be considered as one broadly contemporary complex. Therefore, if any proto-mining technique had developed at the Worthing Group mines, it is highly likely that it would have been recorded at any of the four well excavated mine complexes, which to date it has not. Of course, simpler features may have been buried by later workings, but even when drift mines were recorded, such as on Harrow Hill, they proved to be contemporary with deep mining.

If a more variable approach to pillar and room mining is found away from the Worthing Group, such as the Chichester Group and Wessex Group mines, is unknown, mostly because the mine features at these sites have only been partially excavated. A form of opencast mining has been recorded at Durrington (BOOTH & STONE, 1952), close to the famous henge monument. However, these are dated to the Late Neolithic and are therefore much later than deep mining. Shallow Class 1 mines in the form of shallow pits, between 1 m - 2 m of depth, have also been recorded at Martin's Clump (BARBER *et al.*, 1999, p. 34), but again these are broadly contemporary with deep mining in Sussex, if not slightly later.

This paper has shown that it is the method of pillar and room mining, combined with the drive to extract flint from deep seams that connects mines across Northwest Europe, including those in Southern England. This methodology is unlikely to have developed independently across Northwest Europe at the same time, without a high degree of connectivity between the sites. It is also improbable that the intricate, difficult and developed method of pillar and room mining could have been passed to new communities through informal and short-lived contact events. Therefore, the techniques and the methods at the core of this technique would have had to be learnt first hand, by direct experience of their use within the confines of the mines. Other knowledge, from learning where to look to the right flint, to the very end of the extraction process, must have also been passed on to the next generation during seasonal episodes of deep mining.

9. Conclusion

This paper began with a question on the beginning of flint mining in Southern England, but as the newly obtained dates from Long Down demonstrates, there is now a question to be asked on the end of mining in the region. Therefore, it may be easier to form a narrative on why mining began, based on its continental connection, than why it ended.

Naturally, there is still a wealth of information yet to be excavated from Neolithic mines across Northwest Europe that will influence current debates. But on the evidence available at present, this paper has shown clear links between both Southern English and continental sites. Further, these links were being expressed in the practice of deep pillar and room mining at exactly the same period. Overall then, mining in Southern England can be considered as part of a Northwest European tradition, rather than separate to it. Ultimately, this strongly infers that deep mining documents the direct movement of communities across the Channel sometime prior to the start 40th century BC.

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A gunflint production centre at Masnuy-Saint-Jean (Jurbise, prov. Hainaut, Belgium)

Anne HAUZEUR, Gerhard TRNKA, Michael BRANDL & Hélène COLLET

Abstract

One of the huge workshop complexes for gunflint manufacture in the Mons basin was established by the French '*caillouteur*' Annet Bigaud, during the 1820s, at Masnuy-Saint-Jean. The quality of the flint there made this place one of the largest quarries currently known in the environs of Mons.

In 2013, the opportunity was taken to rediscover those workshops, which are located in privately-owned land. Evidence of quarrying and knapping was observed. As Jacques Breuer wrote (1955), the quarry features are now a pond, but heaps of cores and of debitage remain. These are several metres wide and high, and contain hundreds of thousands of typical blade remnants and cores. It is obvious that blanks were prepared there, while the gunflints themselves were finished elsewhere, customarily at home.

Keywords: Mons basin, Turonian flint, gunflints, 19th century industrial manufacture.

Résumé

L'un des plus importants témoignages de la production de pierres à fusil dans le bassin montois remonte aux années 1820. Il s'agit des ateliers établis par un « caillouteur » français Annet Bigaud à Masnuy-Saint-Jean. La qualité de la matière première en fait la zone d'extraction et de production la plus importante actuellement connue dans la région de Mons.

En 2013, l'opportunité de redécouvrir ces vestiges, situés dans une propriété privée, mit en évidence l'étendue des vestiges d'extraction et de taille. Comme l'écrivait Jacques Breuer (1955), les structures d'extraction ont été transformées en étang. Par contre les rejets de taille, nucléus et produits de débitage subsistent sous la forme de tas imposants de plusieurs mètres de hauteur. Ces rejets attestent le débitage des supports laminaires sur place, alors que les pierres à fusil étaient produites ailleurs, selon les pratiques en usage.

Mots-clés *: bassin de Mons, silex turonien, pierres à fusil, manufacture industrielle du 19ème siècle.*

1. Introduction

The complex of workshops is located 5 km NNW of the city of Mons, close to the southern border of the district of Jurbise, province of Hainaut (Fig. 1). This, one of the huge gunflint production centres in Belgium, was established by the French '*caillouteur*' Annet Bigaud, during the 1820s, at Masnuy-Saint-Jean. The country of Belgium was at that time part of the kingdom of the Netherlands.

2. History of exploitation

Virtually no information exists about A. Bigaud. He presented himself as a French officer of the artillery or as an extractor of flint, depending on to whom he spoke or wrote.

In 1819 A. Bigaud described himself to the authorities in the Netherlands as 'quarryman' from a quarry belonging to the Count of Glymes, and proposed to prove that the quality of the flint

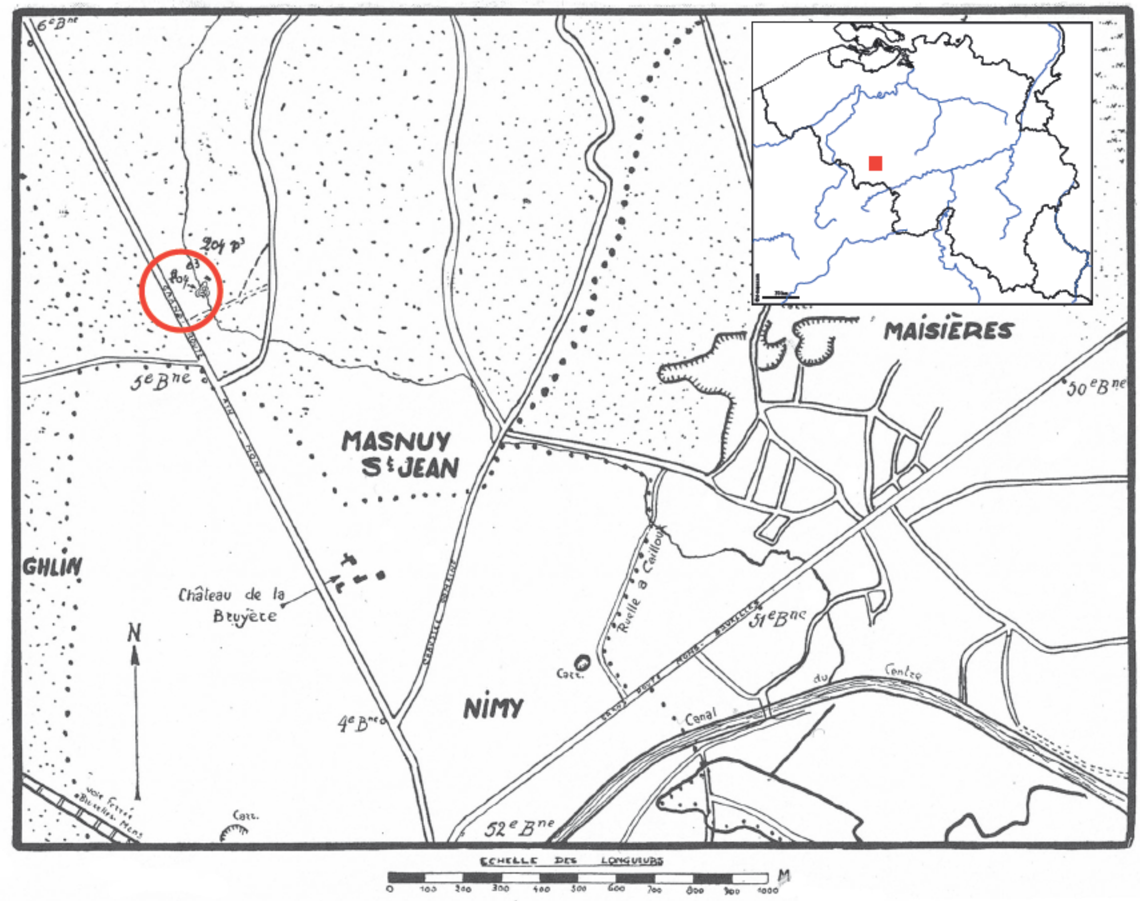


Fig. 1 – Location of the workshops and waste products (red dot and circle) at Masnuy-Saint-Jean (Jurbise, Hainaut). Background map BREUER, 1955, fig. 6.

there was higher than that of English and French gunflints. He also requested a 30-year monopoly to supply the Dutch army. A commission comprising officers and engineers was created to visit the quarry and to examine the quality of the finished products. This gunflint production was considered to be a State affair as this exploitation ensured the independence of the Netherlands in the case of conflict.

In reality the quality of the flint was not the best, as revealed through a shooting test. Further tests were undertaken in 1820 by comparing, inter alia, an English black, a French 'blonde' and an 'indigenous' gunflint. The English gunflint failed after 21 shots, the French after 35 shots, and the indigenous after 54! Based on these results – as luck would have it – on 29th October 1821 A. Bigaud received 1000 florins to begin exploitation with his associate François-Xavier Godart on an industrial scale. But the permission was given for only five years (BREUER, 1961). The team of workers came from the Berry region. On 6th September 1822, A. Bigaud was dismissed from the company under a sentence issued by the court in Mons.

More tests were undertaken some years after Belgium became an independent kingdom. In 1838, the Ministry of War issued an order that only the black indigenous gunflints were to be used. As the quality of this flint was not really as good as it was claimed to be, it was necessary to pass a law obliging the army to use the black local gunflints instead of the French 'blonde' gunflints preferred by the soldiers.

The quarry seems to have been exploited over 20-25 years, and extraction stopped more or less at the time when the caplock mechanism developed. The end of the workshop activities in the Mons area cannot be dated any more precisely than between 1833 and 1845. It seems that the exploitation at Masnuy-Saint-Jean ceased in 1833.

The rediscovery of these workshops can be dated to the early 1950s when Jacques Breuer, curator at the Royal Belgian Museum of Art and History (Brussels), was in contact with Jean Servais, the owner of the site at that time. For J. Breuer it was the opportunity to undertake a study of these forgotten workshops and to write a detailed paper about them. Most of the information presented here comes from this work (BREUER, 1955).

In 2013, the opportunity was taken to rediscover those workshops once more. They are located on privately-owned land. The present owner gave us authorisation to investigate the site. The various features seem not to have changed since they were described by J. Breuer.

3. LANDSCAPE EVIDENCE

As the workshop complex is located on private land, and in order to respect the wishes of the present owner, its exact location is not given here. As it is also considered to be part of the region's industrial past, well preserved and virtually untouched, it would be worth considering its inclusion on the Cultural Heritage list of the Walloon Region, thereby protecting it for the future.

In the wooded private park, numerous heaps of flakes and debitage are still clearly visible. The estimated surface area of the production site is about one hectare, based on the LIDAR image of the area (Fig. 2). The heaps are several metres wide and high, containing hundreds of thousands of typical waste products: cortical blades or flakes, irregular blades, proximal parts of blanks, exhausted cores. Depressions situated between those heaps could be considered as shallow extraction pits (Fig. 3), although the vegetation cover of all the area makes this hypothesis hard to corroborate. Indeed, if these had been shallow quarry pits, this would be contradict Breuer's suggestion that only the lowest flint seams were good enough to be exploited. An alternative proposal could be that these were the knapping places for blank production.

According to J. Breuer (1955), the present-day pond near the house corresponds to

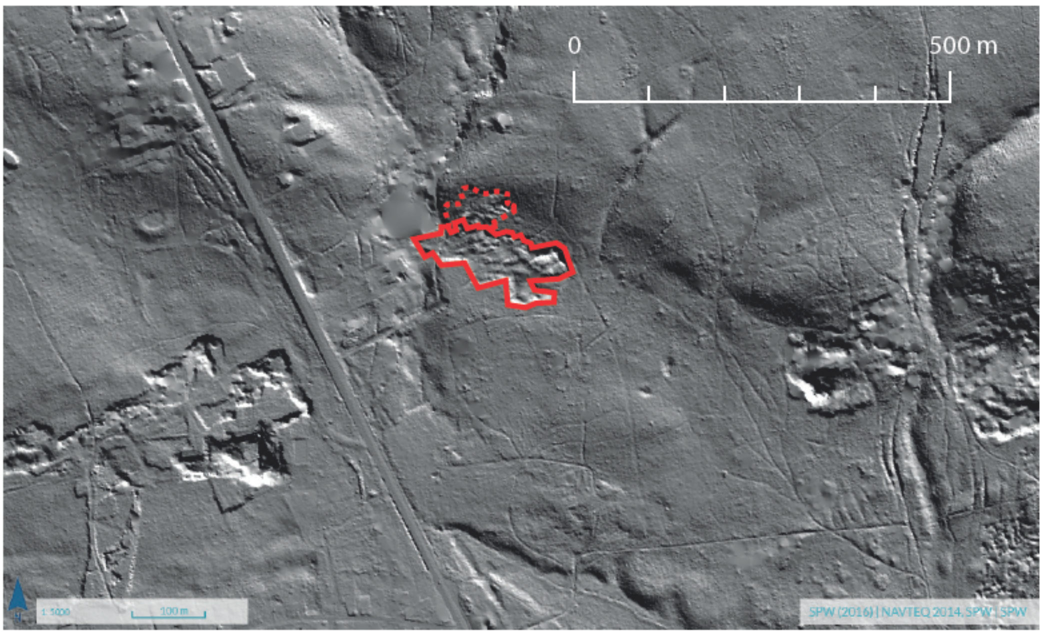


Fig. 2 – Exploited area with the '*Pingenbauten*' relief (red limits) clearly visible in the LIDAR view, and matching our field observations. LIDAR © Navteq 2014 SPW (http://geoportail.wallonie.be/WalOnMap/).

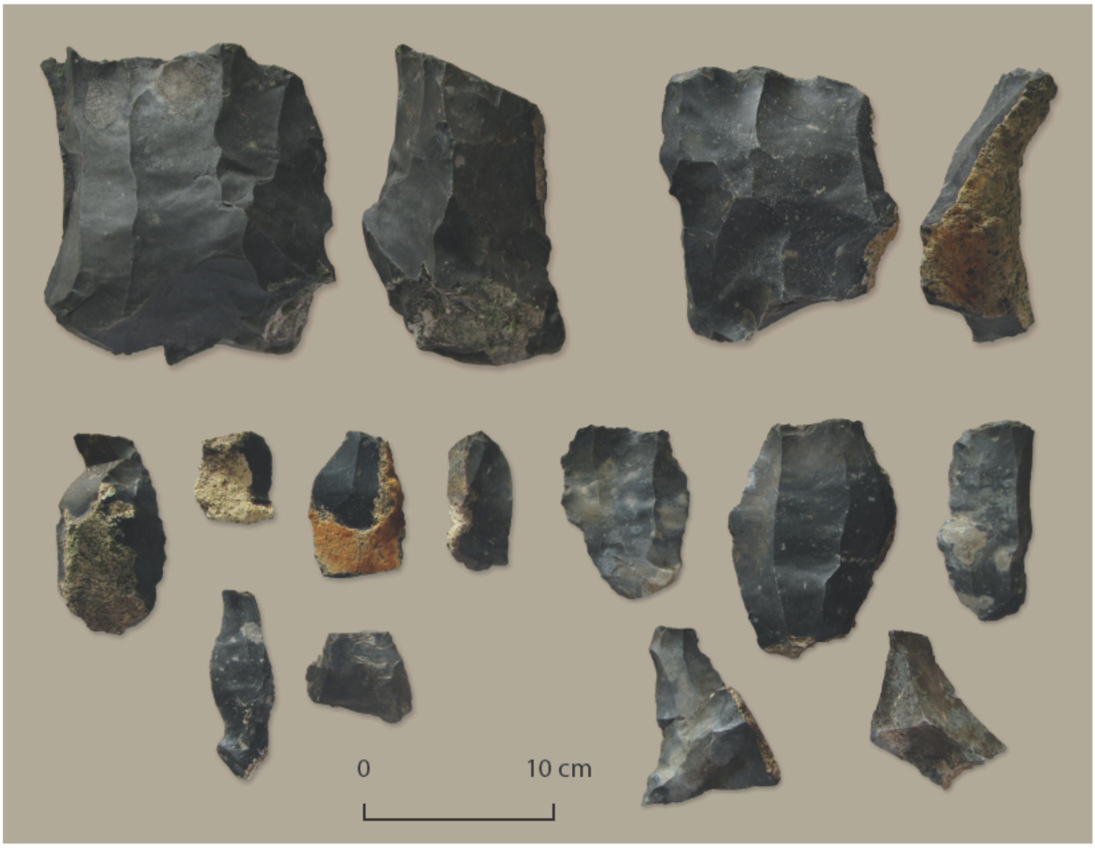
Fig. 3 – Typical '*Pingenbauten*' landscape at Masnuy-Saint-Jean, December 2013. Picture: A. Hauzeur.

a quarry. Nobody has checked this idea, however. On the opposite side of the main road from Nimy to Ath a street called '*rue des Carrières*' (Quarries street) could refer to flint quarries for gunflint production and also for earthenware production – as is the case at Ciply and Spiennes at the end of the 19th century.

4. COLLECTED MATERIAL

Some samples were collected *in situ* with the agreement of the present owner. They confirm the descriptions made by J. Breuer (1955) and by L. Letocart (1957). Evidence of gunflint preparation lies everywhere in the area near the pond: short blade cores, flakes and short blades. But neither sized blade segments nor finished products have been found during our first examination.

The collected cores are characterised by a single flat striking platform. All, or virtually all have cortical spots at the back (Fig. 4). Overhangs are prominent, and hinges are systematically visible, indicating core exhaustion. The collected



geological age	Cretaceous (Turonian)		
color acc. to Munsell	N3 Dark Gray - N2 Grayish Black - N6 Medium Light Gray		
material type	spiculitic flint		
natural surface	subprimary - residual		
averaged inclusion abundance according to Stevenson (2012): 1 very scarce (1-5%); 2 infrequent (5-10%); 3 frequent (10-50%); 4 abundant (>50%)			
fossil inclusions	microscleres (sponge spicules)	monaxons	4
		triaxons, tetraxons	1
	peloids		1
	marine detritus (POM)		3
	opaque organic phases		2
	calcispheres		1
	intraclasts		3
non-fossil inclusions	Fe-oxides		1
	Fe-sulfides		1
	chalcedony (cleft filling mineral)		2

Fig. 5 – Visual and stereomicroscopic characterisation of raw material from Masnuy-Saint-Jean.

blades and flakes are irregular and not standardised (Fig. 4). Cortical or not, they all belong to the preparation phases. The last removed scars indicate that blade blanks could be around 15 cm long and up to 5 cm width. Sometimes the impact of an iron hammer head is visible on the plain platform remnant with a very prominent bulb.

Blanks were obviously prepared here, while the gunflints themselves were finished elsewhere. At the northern border of the ownership a street is labelled '*rue des Pierres à Fusil*' (Gunflints street). It obviously refers to the finished products, which may have been made at that place in (one of) the workers' cottages in the hamlet. According to custom, the French '*caillouteurs*' ('stone workers') normally brought the nodules home to prepare them, and knapped the blade blanks and transformed them into gunflints there (EMY, 1978, p. 79-80). But sometimes they produced the first stages of debitage in the vicinity of the quarry before bringing the blanks back home.

As the factory was established by a French worker with other workers coming from the Berry region, the French tradition of making gunflints was followed. But until now none of the typical finished products has been discovered. Maybe an excavation will provide more information.

5. Raw material and microscopic analyses

For raw material characterisation, macroscopic (visual) and microscopic investigations were conducted on freshly cut specimens (see results in Fig. 5). Typically, the material from Masnuy-Saint-Jean appears darker than that from Nouvelles and Spiennes, between blackish grey to greyish black with characteristic whitish dots. This fits with

Fig. 4 – (opposite page) Characteristic cores and waste of gunflint blank production collected at Masnuy-Saint-Jean. Picture: A. Hauzeur.

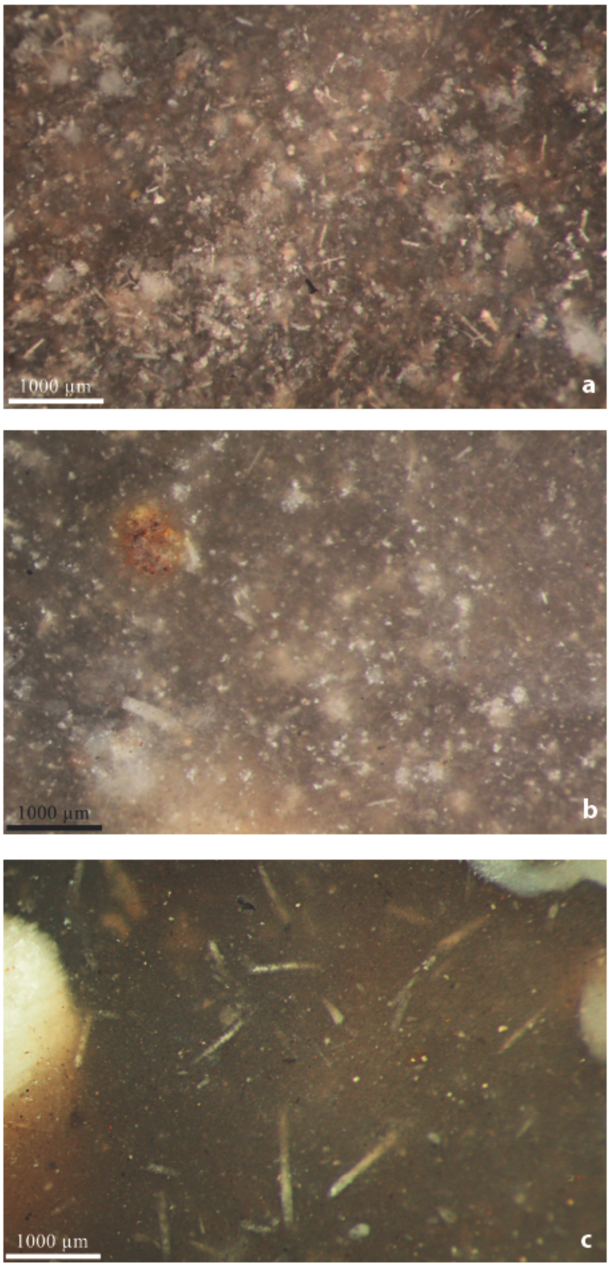


Fig. 6 – a. Masnuy-Saint-Jean archaeological sample, produced on a freshly cut rock surface (unpolished) at 40x magnification and under water immersion (M. Brandl);
b. Spiennes geological sample (MOREAU *et al.*, 2016);
c. Nouvelles geological sample (M. Brandl).

Breuer's description. According to him, the raw material was extracted from the lower seams, the only ones suitable for gunflint knapping.

Microscopically, the dominant features of samples from Masnuy-Saint-Jean are abundant microscleres from marine demospongiae, predominantly monaxons (Fig. 6: a). Additionally, particulate organic matter (POM), intraclasts responsible for the white dots macroscopically visible in the flint matrix, and chalcedony present as a cleft-filling mineral are characteristic for this kind of flint.

Visually and microscopically, the material from Masnuy-Saint-Jean shows no similarities with flints from the Spiennes and the Nouvelles formations, even though all of them are of marine origin. Comparative geological samples (Fig. 6: b, c) illustrate that sponge spicules are also present in both the Spiennes and Nouvelles material (Campanian), but not in the same amounts as in the Masnuy-Saint-Jean archaeological sample (STEVENSON, 2012). Given the current state of research and with all due caution, the Masnuy-Saint-Jean sample can most likely be assigned to alterite layers of Turonian origin according to the geological map.

It is planned to test this preliminary assignment through geochemical analyses using LA-ICP-MS and to compare it with previously analysed geological samples, accompanied by new field sampling campaigns.

6. CONCLUSION

The quality of the flint made this place one of the biggest gunflint production centres in the Mons area. The gunflints were mostly exported and sold to the Netherlands, then to the new Kingdom of Belgium. Nevertheless this production was of short duration, lasting only two to three decades, and employed few workers.

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We especially thank Mrs Françoise Servais, daughter of Jean Servais, who welcomed us the first time on the site.

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Geo-resources and techno-cultural expressions in the south of the French Massif Central during the Upper Palaeolithic: determinism and choices

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Abstract

The petro-archaeology of silicites defines the origin of the siliceous raw material found in archaeological sites. Recent methodological advances, like more precise facies definition, determining the provisioning path for silicites in studied sites, the 'evolutionary chain concept' and precise mapping of siliceous mineral domains, enable us to identify not only the location where any particular flint formed (primary outcrop), but also where it was collected (primary and secondary outcrops).

Exhaustive studies of Upper Palaeolithic flint collections from sites in the south of the French Massif Central (Late and Final Gravettian: 'Le Blot' and 'Le Rond-de-Saint-Arcons'; Badegoulian: 'Le Rond-du-Barry' and 'La Roche-à-Tavernat') reveal an unexpected diversity of raw materials indicative of huge territories being exploited. Accordingly, we have developed a new figurative model for the origins of lithic raw material discovered in these archaeological sites, not as a site-centred radiant form, but more akin to an interrelated network of places, which is congruent with ethnographic and geographic data. The different types of silicite in the lithic industries correlated with their position within the 'evolutionary chain' allow speculation on the choices made by prehistoric hunter-gatherers within the natural constraints they faced. This in turn enables the addition of the mineral space into reconstructions of the paleo-social-space.

Keywords: Upper Palaeolithic, Petro-archaeology, French Massif Central, evolutionary chain of silicites, paleo-geography, territory, settlement.

Résumé

La pétroarchéologie du silex s'attache à définir les origines des silex retrouvés dans les sites archéologiques. Au vu des avancées méthodologiques récentes (définition toujours plus précise des faciès, vision dynamique du parcours du silex dans son environnement – chaîne évolutive –, mise en place d'une cartographie précise des domaines minéraux siliceux) il est aujourd'hui possible de préciser non seulement le lieu de formation du silex (gîte primaire) mais également son lieu de collecte (gîte primaire ou secondaire).

L'étude exhaustive des silex de collections archéologiques du sud du Massif central à plusieurs moments-clés du Paléolithique supérieur (Gravettien récent et final : « Le Blot » et « Le Rond-de-Saint-Arcons » ; Badegoulien : « Le Rond-du-Barry » et « La Roche-à-Tavernat ») a permis la mise en évidence d'une diversité insoupçonnée de matériaux représentatifs d'un vaste litho-espace (espace géographique comprenant l'ensemble des matériaux considérés). Nous proposons donc un modèle de représentation de l'origine et de l'acquisition des matières premières retrouvées sur un site archéologique, non plus sous une forme sito-centrée (en étoile), mais sous la forme d'un réseau de lieux, plus en accord avec les données issues des observations ethnographiques et géographiques. La représentation des différents types de matériaux au sein des industries lithiques, ainsi que leurs modes d'introduction sur le site, permettent de distinguer les choix opérés par les hommes et les contraintes naturelles subies, autorisant dès lors l'inscription sémantique du litho-espace dans un essai de reconstruction du paléo-espace social.

***Mots-clés** : Paléolithique supérieur, pétro-archéologie, Massif central français, chaîne évolutive des silicites, paléogéographie, territoires, peuplement.*

1. INTRODUCTION

The French Massif Central is an area deemed to be poor in silicites (by silicites we refer to all silicified rocks of chemical, biochemical or diagenetic origin at the exception of sandstones [and particularly quarzitic sandstone]. It allows avoidance of the term 'flint,' whose meaning is controversial and leads to misunderstandings between geologists, petrographers, sedimentologists and archaeologists. In this manuscript, we thus use the term 'flint *sensu stricto*' to refer to rocks made of siliceous epigenesis and carrying a cortex, and the term 'flint' in the archaeological sense to refer to the lithic objects worked by man), both in quantity and quality (e.g. VIRMONT, 1981; BRACCO, 1992, 1994a, 1995, 1996; BOSSELIN, 1997; SURMELY *et al.*, 1998, 2008; SURMELY, 2000; SURMELY & PASTY, 2003; ANGEVIN, 2010). However, since the 1980s, the pioneering work of A. Masson (1981) then, during the following thirty years, the surveys carried out by various participants in regional research, showed the inaccuracy of this silicite poverty model (FERNANDES *et al.*, 2008a, 2008b, 2009; FERNANDES, 2012). Various silicites are indeed present, even if the heart of the massif does not contain as much as its sedimentary margins, such as the south of the Paris Basin with its famous blonde flints *s.s.*, the Rhone corridor or the Aquitaine Basin. Primary deposits containing large quantities of silicite of good quality, but often of reduced extent, are common: for example, the Saint-Léger-du-Malzieu (Lozère) deposits, or Saint-Pierre-Eynac (WRAGG-SYKES *et al.*, 2017), Arlanc and the Borne Valley in Haute-Loire, the Limagne of Auvergne in Puy-de-Dôme or the Aurillac Basin in Cantal. Similarly, secondary silicite deposits in alluvial contexts are numerous and contain siliceous pebbles with volumes of several cubic decimetres, such as the multiple secondary deposits of Naussac (Lozère) in the upper Allier Valley. Thus, in contrast to its reputed paucity in silicites, the French Massif Central is far from deprived of materials suitable for knapping.

The aim of this work is to address the reconstruction of past territories based on data from petro-archaeology. Our analyses integrate the notion of the evolutionary chain specific to silicites and are founded on detailed petrographic characterisation of all the elements of an archaeological series, without prior visual sorting. The analyses make it possible to identify economic behaviour and to determine and describe relationships between localities. Careful examination of both the most abundant and the rare materials, sometimes present in a single specimen, allows the extent of the supply area to be established and the procurement patterns of prehistoric groups to be defined.

2. MATERIAL AND METHOD

2.1. Read and understand silicites

Petro-archaeology (ŠTELCL & MALINA, 1970) is a discipline at the crossroads of geology and archaeology, and the outcomes of the discipline are essential to understanding the economic and social behaviours of prehistoric humans. However, for various academic, scientific and methodological reasons, petro-archaeology has long remained at the margins of its two mother-sciences and is often considered as an appendix to typological and technological studies, which, during the twentieth and the beginning of the twenty-first century were the leading methodologies used in archaeological flint analysis.

The petrography of siliceous rocks has two main interests for prehistorians:

1) It contributes to the reconstitution of techno-economic systems by documenting the first phases of the *chaîne opératoire,* namely raw material procurement coupled to lithic technology, giving the modes of introduction of the silicites into sites;
2) It highlights supply routes, supply areas and more generally helps to identify prehistoric territories.

Our approach is based on two complementary methods: the so-called 'classical approach', widely developed in the 1980s by M. & M.R. Séronie-Vivien (1987) in the Aquitaine Basin and a 'dynamic approach', integrating the concept of evolutionary chain of flint (*infra*). Indeed, the work of the petro-archaeologist is not only to identify the genetic type of a silicite, pointing to its stratigraphic origin and the initial geological formation from which it originates, but also its gitological type, which allows the place where it was gathered by prehistoric man to be located. The singularity of our approach is therefore to give a temporal dimension to silicites, integrating them into evolutionary chains, a concept defined and developed in Auvergne (France) during the last ten years by P. Fernandes, V. Delvigne, M. Piboule and J.-P. Raynal (FERNANDES & RAYNAL, 2006; FERNANDES *et al.*, 2007, this volume; FERNANDES, 2012).

The concept is based on the observation that silicites, which are metastable in their environment, undergo transformations to their mineral structure during each physico-chemical modification occurring in their place of origin and during changes in their locations. This evolution, which is dependent on mineralogical modifications induced by a search for the state of equilibrium represented by quartz (THIRY *et al.*, 2014), not only affects the external envelope of the rock, but its total volume. It is expressed at different scales, namely: macroscopic, mesoscopic, microscopic and ultramicroscopic. Thus, during analyses, it is necessary to quantify the degree of evolution of the figured elements (or allochems) and of the matrix (or orthochem), in order to revisit the archaeological object at each stage of its evolutionary chain. Of course, before carrying out this operation, it is necessary to have first described the evolutionary chains of the geological silicites, since each type of silicite has a distinct evolution. Several different geological types may thus derive from the same genetic type. Identifying and tabulating the various evolutionary stages play an important role in the archaeological reconstitution of prehistoric economies, because humans have made abundant use of secondary deposits (TURQ, 2005).

Silicites may therefore have lived a complex history before their collection by humans and they bear characteristics generated in the different environments they passed through. The deposits are divided into eight basic categories which can be combined and mixed: primary deposits; sub-primary deposits; alteritic deposits; colluviums; alluvial deposits of active or fossil river courses; coastal beaches, and moraines.

Just as the collection area of lithic raw materials can be confusing within primary deposits (in the case of flint mines for example), collection areas may also be remote from their primary source, such as pebbles found on old terraces or on beaches.

In addition to the weathering analysis of siliceous rocks (*supra*), the reading of the last surface state (LE RIBAULT, 1977) of the neocortical zones or of the natural lithoclase, identifies the silicite collection site, which in turn may reveal particular human behaviours.

As we have shown in our previous works (DELVIGNE *et al.*, 2014a, 2014b; DELVIGNE, 2016), this degree of precision in petrographic analysis is important. The diversity, quantity and type of introduction of materials, from coherent geographical areas into archaeological sites (i.e. geotops), makes it possible to identify either a direct, or indirect, procurement strategy; which in turn reflects the extent of territories used in the past.

2.2. Travel, route, territories: the contribution of geography

The tools of geology are employed in the analysis methodology for silicite types, but it is those of geography which are used for elucidating territoriality.

In the Western concept of space, the smallest piece of land is owned and managed by a physical or legal entity, without there being, in theory, an empty area at the scale of the 'territory' of a group. A territory is perceived as being the sum of the individual possessions, the national territory for example. However, this structuring of space differs from that of current and sub-current nomadic peoples, notwithstanding their economic system (Fig. 1). In these, named places corresponding to points of interest, or *foci*, of particular activities are recognised. These *foci* are also linked by routes that have somewhat different status to that of the former (the non-places of M. AUGÉ, 1992). Apart from regular routes and identified locations, areas exist that are rarely frequented and are 'outside' principally frequented zones (TINDALE, 1974; COLLIGNON, 1996). Although the peoples of the Palaeolithic are considered

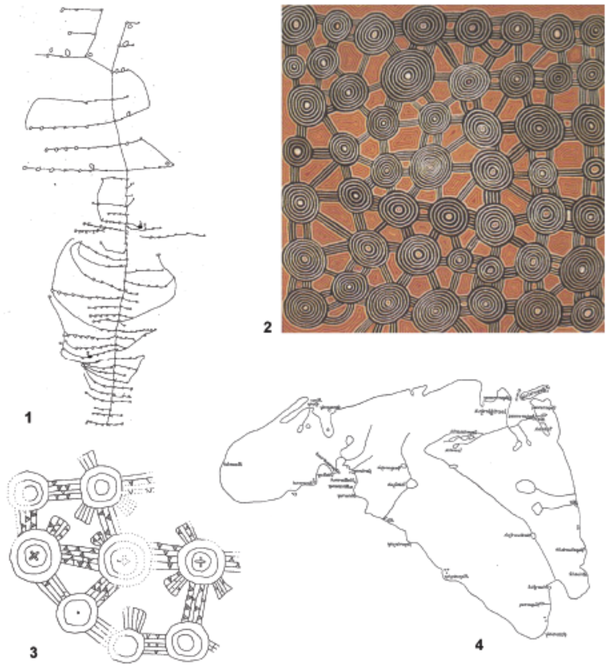

Fig. 1 – 1: Map of a Nigerian Tuareg Peul (GOULETQUER, 1990, p. 486); 2: Tingari dot painting, west of Kiwirrkurra, Australia (P. Bindon); 3: Amerindian map, Spiro mound, Oklahoma, engraved on a shell (LAFFERTY III, 1994, p. 202); 4: Inuit map (RASMUSSEN, 1930, p. 11).

nomadic, current scientific representations of past Palaeolithic territories appear as cohesive and homogeneous zones covering large areas. Sometimes these zones illustrate the spatial distribution of certain objects, or perhaps the region occupied by a given 'culture' (defined by the distribution of related sites), or as maps on which radiating lines connect resources to 'camps' (as in the case of raw material studies). Here, we propose to adapt the methods of ethnography, and social geography, to prehistory and to consider prehistoric territories in the form of networks of places (DEBARBIEUX, 1995, 2009).

To do this, it is first necessary to determine the origin of silicites found in archaeological sites, since in addition to demonstrating their abundance, these objects intrinsically contain spatially valuable data (e.g. MEROC, 1943; VALENSI, 1955; DEFLANDRE, 1966; MASSON, 1981; DEMARS, 1985; MAUGER, 1985). However, the simple assimilation of the litho-space (considering a given archaeological level and for which the establishment of deposits is well known, we call litho-space, the geographical space defined by the maximum extent sketched by the origin of the raw materials found in this level) of a single site into the exploited geographical space and/or territory of a given group is unsatisfactory, because it fails to consider the underlying humanly contrived mechanisms relating to the presence of the materials in the sites. Neither does it account for behavioural factors external to the site, such as the possible places frequented that leave no direct material trace. Consequently, the analysis remains site-centric, which, from the point of view of spatial management and territorial study, is unsatisfactory, since social geography has shown that it is the totality of interconnections between places that carries spatial meaning and determine territorialisation (e.g. BONNEMAISON, 1981; BERNUS, 1982; DI MEO, 1998). Therefore, only the networks of the various litho-spaces obtained for sub-contemporary sites and the integration of the geographical values (in the spatial, social and economic sense) of all available elements can lead us to an understanding of the management of space at different times during the Palaeolithic.

In order to reconstitute the territories of the past in the form of a network of places, we have adopted three postulates:

1) a paleo-ethnographic truth for the studied elements: all objects coming from the same level can be considered to belong to the same set (so long as the taphonomic integrity of the level in question is convincing and the remains have 'chrono-cultural homogeneity');
2) territorial temporal stability: since territories are primarily societal constructions, their structure does not vary significantly while the cultural system governing them persists; the absence of strict contemporaneity between sites is therefore not a problem while ever cultural entities remain coherent (i.e. that of prehistoric techno-cultures);
3) structural simplification modifies networks: the recurrence of and crossing of routes permits the registration of two distinct places within the same network. This is a direct inference from the second postulate since a temporal equality is equivalent to a spatial equality.

2.3. The Body of the Study

The studied corpus comes from eight archaeological sites belonging to the second half of the Upper Palaeolithic (Fig. 2) and consists of about 20,000 artefacts. While the southern sites of the Haute-Loire Department ('Le Blot', 'Le Rond-de-Saint-Arcons', 'La Roche à Tavernat', 'Le Rond-du-Barry', 'Cottier') provided the major part of the study, the addition of some northern sites ('La Contrée Viallet', 'La Faye Godet', 'La Grange Jobin') enriched the results. In the rest of this work, we deliberately ignore techno-economic aspects - namely, the reconstruction of the *chaîne opératoire* using the domain of procurement of the lithic materials: local (<10 km from the site), semi-local (10-100 km from the site), distant (>100 km from the site) (for more details see DELVIGNE, 2016) - preferring to focus on the origin of geo-resources and the notion of prehistoric territories.

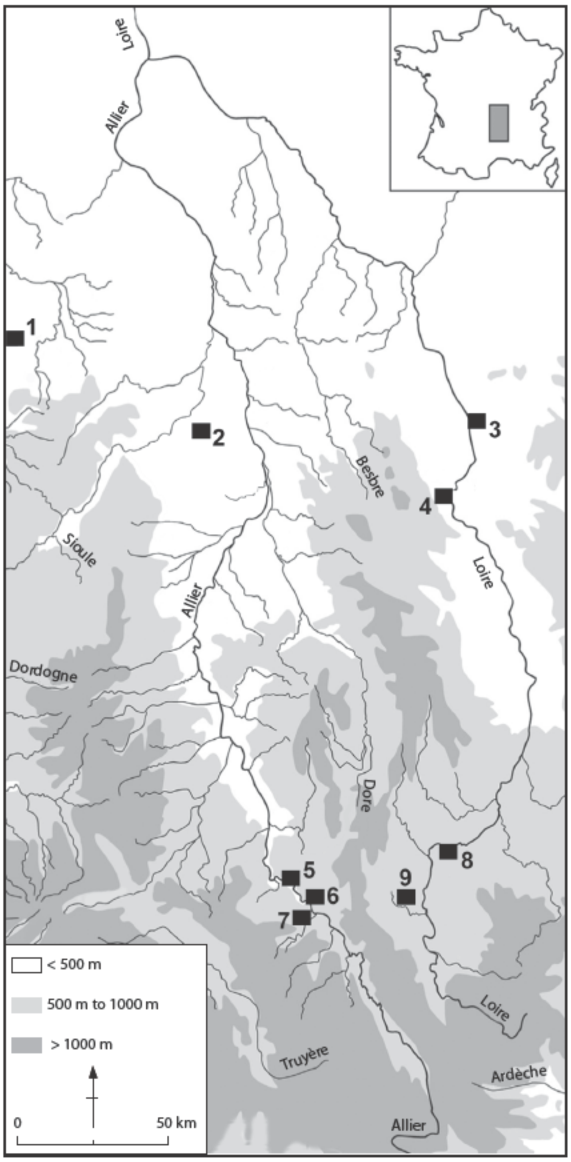

Fig. 2 – Location map of the sites mentioned in the text. 1. La Faye Godet; 2. La Contrée Viallet; 3. La Grange Jobin; 4. La Goutte Roffat; 5. Le Blot; 6. Le Rond de Saint Arcons; 7. La Roche à Tavernat; 8. Cottier Cave; 9. Le Rond-du-Barry.

3. RESULTS

The results concern different time intervals in the Palaeolithic of Auvergne: the Late Gravettian, the Final Gravettian and the Badegoulian. These three chronological windows occur within a particular climatic context, namely during and after Glacial Stage 3 (GS3) - when global climate exhibits significant contrasts. We provide here the archaeological synthesis from the detailed petro-archaeological analysis of the series studied. The raw information relating to the diagnosis of the different types of silicites, too long to expose in the context of this paper, are presented in the thesis of one of us (DELVIGNE, 2016).

3.1. Late Gravettian

After a settlement hiatus covering the whole Early Upper Palaeolithic period, i.e. Chatelperronian, Aurignacian and Early and Middle Gravettian, the first signs of occupation of the south-east of the French Massif Central appear in the Late Gravettian, in levels 35 to 52 of 'Le Blot Rock Shelter' at Cerzat (Haute-Loire) (DELPORTE, 1972; BUISSON, 1991; KLARIC, 1999, 2000). This site seems isolated in the landscape of the Late Gravettian, since its closest contemporaries are about 150 km to the south in Languedoc and to the west in Périgord (KLARIC, 2003).

Based on unpublished stratigraphic work by J.-P. Daugas, who was the architect of the revision and homogenisation of the very complex stratigraphy of 'Le Blot Rock Shelter' initially revealed by the works of H. Delporte, and on our own observations (vertical mapping of object refitting, DELVIGNE, 2016), we have

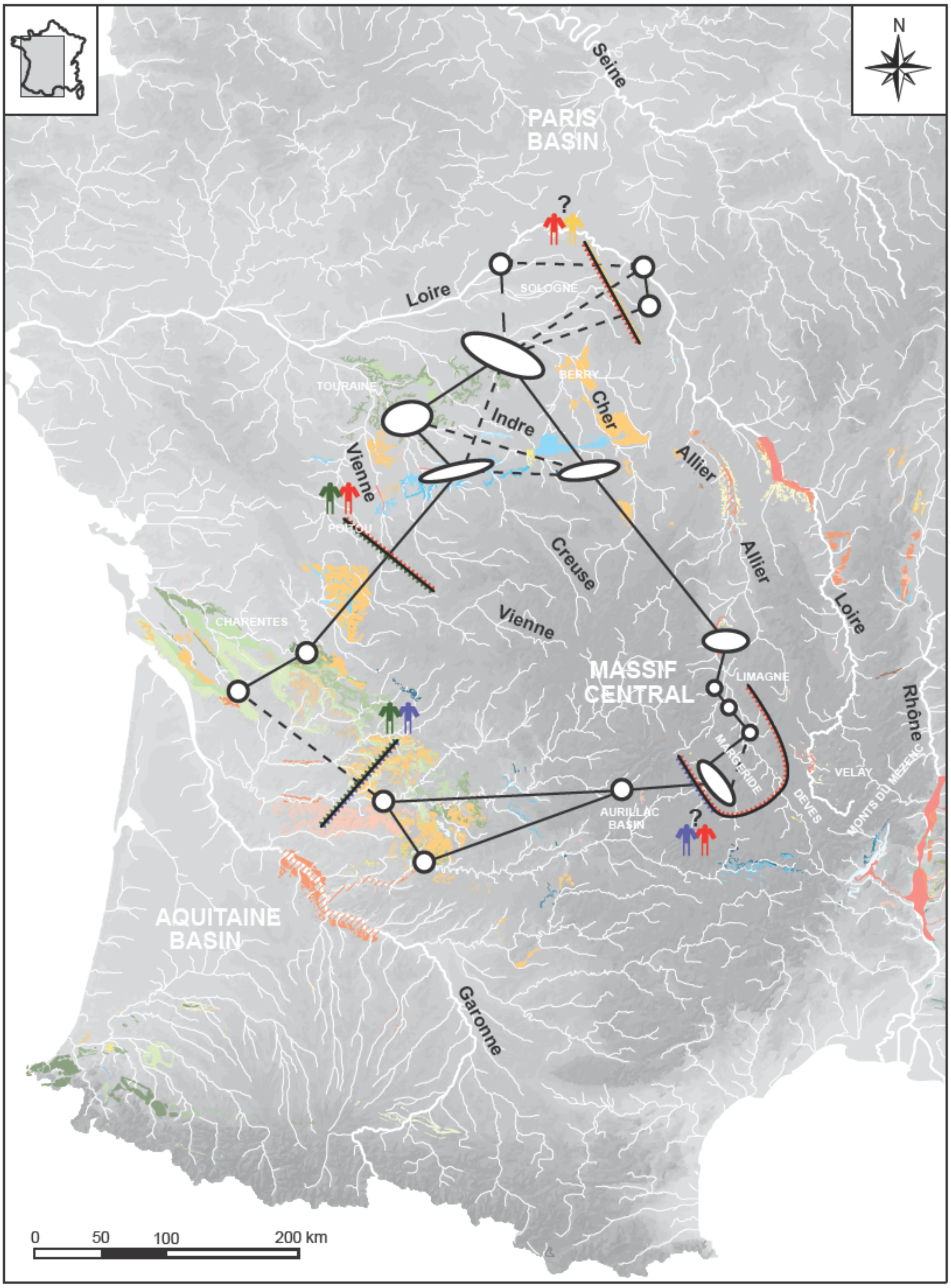

Fig. 3 – Map of the Late Gravettian territory. White circles indicate areas of special interest (*foci*); solid lines illustrate relationships proven by material evidence; dashed lines correspond to relations supposedly induced by the structural simplification of the network; the herringbone lines represent possible boundaries between human groups; the pictogram of two individuals indicates likely trade areas. The coloured areas represent the formation with silicites; colours follow the international stratigraphical chart.

grouped the different levels attributed to the Late Gravettian of 'Le Blot' into two large sets: the lower set G1, and the upper set G2. Each contains about thirty different types of flint in varying quantities, ranging from isolated pieces to several hundred objects. Petro-archaeological analysis shows that only a few silicites were collected in the local area, and most of the tool-kit is made of silicites from more distant domains. Materials from the semi-local domain show close relationships with those of the northern lands of Limagne and western Margeride: Truyère Valley, Aurillac Basin and even Aquitaine Basin. Remotely sourced materials point to the south of the Paris Basin (Pays Fort, Berry, and Touraine), the Poitou, and Charentes (Fig. 3).

The harvested silicites, at least those of the Limagne, seem to correspond to milestones on the route taken by humans before their arrival at 'Le Blot'. The absence of material from the high valleys of the Allier and Loire and the hiatus of sub-contemporary sites in the regional space, suggests that 'Le Blot' should be considered as a '*terminus*' on the margins of a main territory anchored further to the north in the southern border of the Paris Basin where there are known occupations attributed to the Late Gravettian (KLARIC, 2003). This hypothesis is reinforced in the upper ensemble, G2, where there appears to be a shift away from the mineral resources of the Limagne to the marine Cretaceous flints *s.s.* of the southern margins of the Paris Basin (Touraine and Berry). Nevertheless, during the entire Gravettian period, no modifications were made to either the availability of materials or the function of the site (which was a temporary camp with activities related to the hunt, namely, the manufacture of lithics and repair of weapons used for reindeer hunting).

In this hypothesis, the upper Allier Valley considered as a hunting area, would therefore be frequented only during expeditions for the procurement of animal resources, especially meat. The change in lithological diversity between the lower and upper sets, G1 and G2, is the only real change in livelihood activities; the other registers remaining unchanged. This may mean there was a change of group, a partial abandonment of Velay followed by a return, or a change in the status of the Limagne. Finally, besides its probable chronological position in the second part of the Late Gravettian (*sensu* KLARIC *et al.*, 2009), the techno-economic and lithological variability of the assemblage of 'Le Blot' seems to hinge on the type and duration of occupation, features that are themselves subordinate to the status of the site within the territory.

3.2. Final Gravettian

Following the Late Gravettian, the occupation of the upper Allier Valley continues during the Final Gravettian, identified in layers 22 to 34 of 'Le Blot' (DELPORTE, 1972; VIRMONT, 1981; BOSSELIN, 1992a, 1992b, 1997, 2007; SURMELY & HAYS, 2011) and in Level C of 'Le Rond-de-Saint-Arcons' (BOULE & VERNIÈRE, 1899; DELPORTE & VIRMONT, 1983; FONTANA *et al.*, 2014).

The lithic raw material supply is marked by the virtual absence of local materials and by the rarity of Limagne and western Margeride rocks. In addition to their large quantity, the contribution of remotely sourced flint (*s.s.*) in the form of entire or barely pre-formed blocks, illustrates an anticipation of future needs, while the rare semi-local silicites present in the archaeological series are probably the result of opportunistic human behaviour. Nevertheless, the absence of local and semi-local materials in the lithic tool-kits is not linked to a lack of knowledge of the environment. Rather, it demonstrates rational behaviour by humans who plan the transport of raw materials over long distances rather than searching for suitable knapping materials in close proximity even though other activities may, of necessity, demand a large part of their time. Similar behaviour is recognised as occurring contemporaneously on the western side of the French Massif Central, between Périgord and Quercy, at 'Les Peyrugues Rock Shelter' (GUILLERMIN & MORALA, 2014).

The three different phases of the Final Gravettian of 'Le Blot' and the small assemblage of 'Le Rond-de-Saint-Arcons', layer C are marked by the similarity of their lithological spectra (Fig. 4) which, like the last occupations of the Upper Gravettian of Le Blot (*supra*), are largely dominated by flint *s.s.* from the south of the Paris

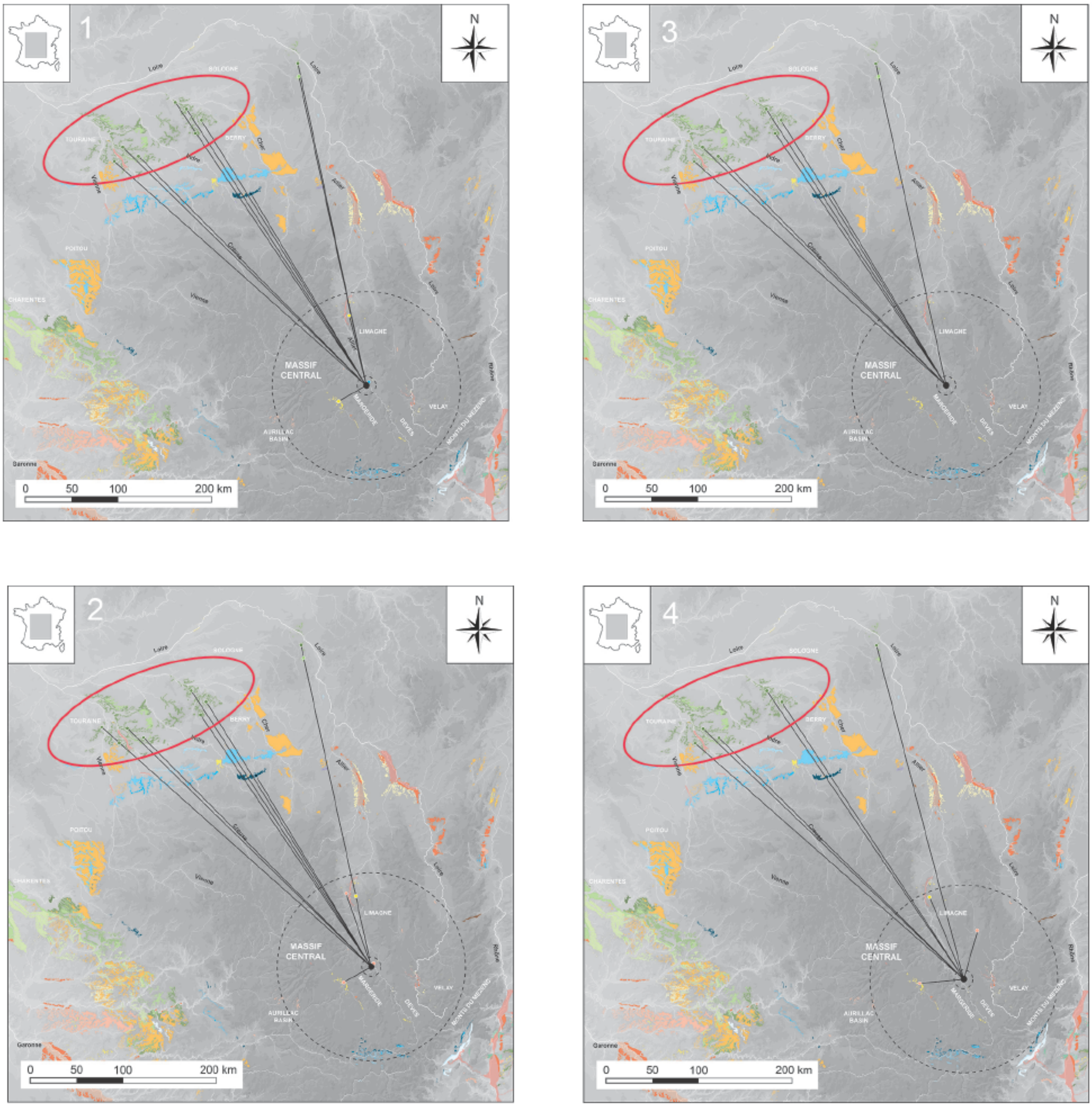

Fig. 4 – Comparison of the litho-spaces of the three sets of the Final Gravettian of 'Le Blot' and the 'Rond-de-Saint-Arcons'.
Red circles show the geographical space from where the lithic raw materials originate.
1: Lower set, P1 of 'Le Blot', number of genetic types = 23;
2: Middle set, P2 of 'Le Blot', number of genetic types = 25;
3: Upper set P3 of 'Le Blot', number of genetic types = 14;
4: Level C of the 'Rond-de-Saint-Arcons', number of genetic types = 14.
The coloured areas represent the formation with silicites; colours follow the international stratigraphical chart.

Basin; notably the Upper Turonian of Touraine and the Lower Turonian of Berry (DELVIGNE *et al.*, 2017). Its quantity and diversity confirm knowledge of the mineral potential of this very distant area (more than 200 km away) and invite us to consider the direct procurement of materials upstream of the route bringing humans to Auvergne, at the southern margin of their territory. There seems therefore to be certain continuity in the mode of occupation and in the status of the upper Allier Valley during the last expressions of the Gravettian. Indeed, in addition to the massive influx of Cretaceous flint *s.s.* from the southern Paris Basin in the Late and Final Gravettian of Le Blot (unequalled in other regional sites), the site functions and activities conducted there seem to persist throughout the complete sequence.

3.3. Badegoulian

After an occupational hiatus of two millennia corresponding to the time range of the Solutrean, the arrival of the Badegoulian marks a break in the management of the space lying between the Loire and Allier valleys. This period is today represented in the east of the Massif Central by eight sites divided equally between the Allier Valley and the Loire Valley. Four are in the northern part of the region: 'La Faye Godet' (LAFARGE, 2014), 'La Contrée Viallet' (LAFARGE, *op. cit.*), 'La Grange Jobin' (PASTY & ALIX, 2010) and 'La Goutte Roffat' (DIGAN, 1993); and four are in the south: 'Le Blot' (DELPORTE, 1972; VIRMONT, 1981), 'La Roche à Tavernat' (BRACCO, 1992, 1994b), 'Le Rond-du-Barry' (DE BAYLE DES HERMENS, 1972; 1974; LAFARGE *et al.*, 2012; LAFARGE, 2014) and 'Cottier Cave' (VIRMONT & VIRMONT, 1973). The ages for these occupations range from 23,900 years calibrated BP to 20,500 years calibrated BP, thus within the accepted temporal variability of this period (DUCASSE *et al.*, 2014). We will focus here on the sites that provided the most convincing results, 'Le Rond-du-Barry' and 'La Roche à Tavernat'.

The 'Rond-du-Barry' Cave, located in Polignac in the Department of Haute-Loire, has a long sequence ranging from the Mousterian to the Middle Ages and recent dates show a continuous occupation of the cavern throughout the Badegoulian (RAYNAL *et al.*, 2014). Based on the techno-typological criteria of the lithic industry, layer F, containing the Badegoulian occupation, has been divided into different sectors which probably have chronological validity (LAFARGE, 2014); a sectorisation that the resumption of excavations after 2016 seems to confirm.

In a space at the interface between the Mediterranean and Atlantic worlds, 'Rond-du-Barry' Cave seems to play a particular role marked by original characteristics: a longer occupation than in other more-or-less contemporary sites; a diversity of activities; a strong recurrence of occupations and a multiplicity of geographical influences, especially southern ones. The analysis of the F-layer artefacts shows that the percentage of local and semi-local materials increases significantly from the beginning of the Badegoulian, illustrating the flexibility of the lithic technical system alongside an expert knowledge of the mineral environment. Local raw materials appear to have been collected from various deposits during other subsistence activities, including hunting, while the contribution of semi-local flints probably comes from gathering them along the route leading to Velay and/or from collection during logistic expeditions whose primary objectives remain difficult to determine. Concurrently, the diversity of flint types increases significantly, reaching 60 genetic types. Among them, the 40 of known origin confirm that forays were made in various directions, not only confirming contact by the population of the massif to the south and centre of the Paris Basin, but also with the Rhone Valley to the east and the Cantal massif to the west.

For comparative purposes, we analysed the origin and management of the geo-resources of the Badegoulian from 'La Roche à Tavernat', situated in the upper Allier Valley at Chanteuges (Haute-Loire). In this site, where the industry is predominantly made on quartz, we have recognised resource management strategies similar to those at 'Le Rond-du-Barry'. The local flints of the Borne Valley exploited at 'Le Rond-du-Barry' are supplemented by quartz at 'La Roche à Tavernat'. Approximately 30 types of flint point to the same localities as those identified for 'Le Rond-du-Barry'. However, if silicites from the Allier Valley are present in Badegoulian sites of the Loire Valley, the reverse is not true and no silicite from the upper and middle Loire Valley has been recognised at 'La Roche à Tavernat'. Perhaps this can be explained by a polarity in human movement.

The origin of the materials found in the Badegoulian sites in Auvergne shows that crossings were made of the main interfluves of the regional space including the Margeride, Devès and Mézenc Mountains, also, crossings were made in the middle reaches of the major

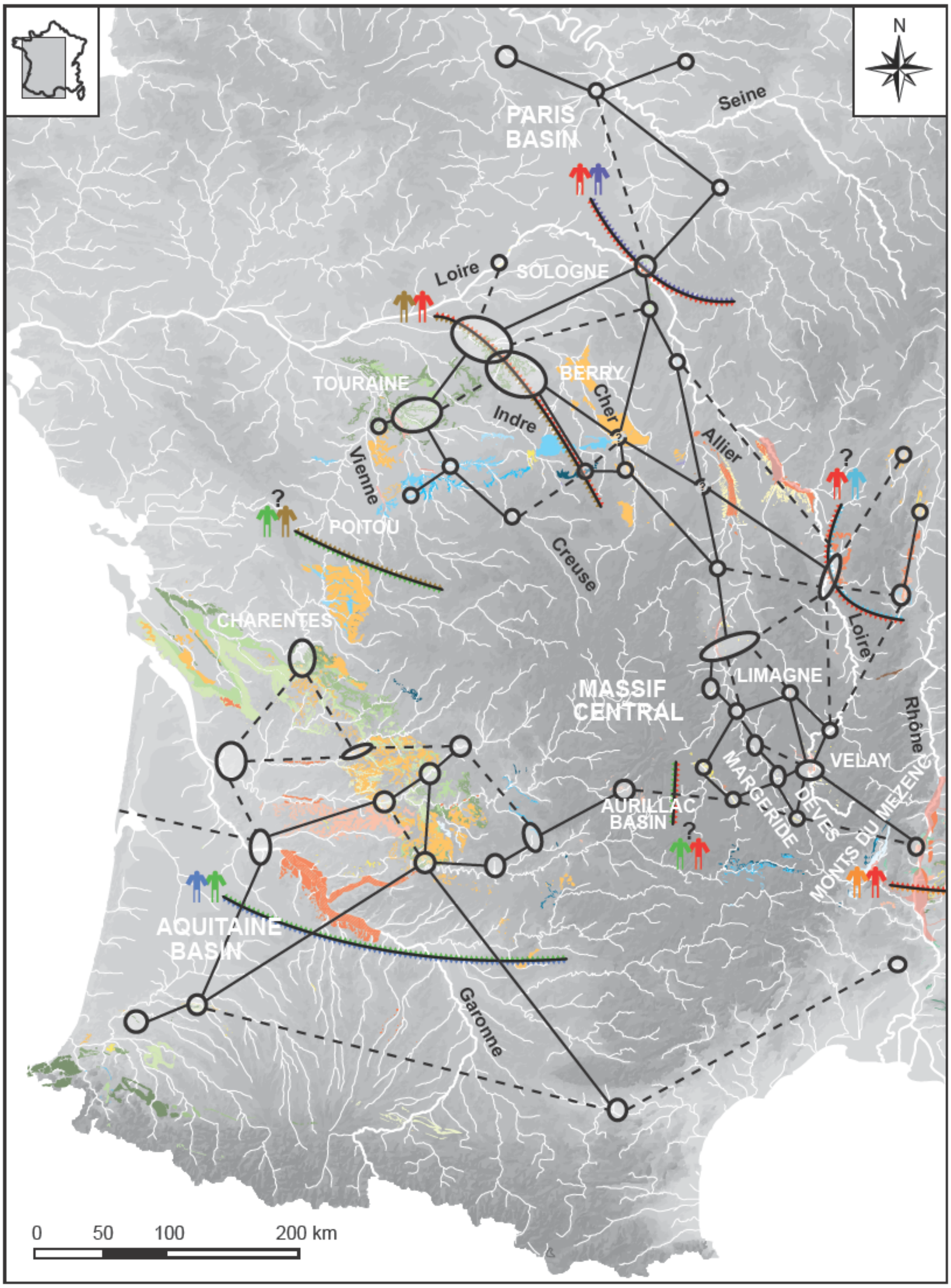

Fig. 5 – Map of Badegoulian territory. White circles indicate areas of special interest (*foci*); solid lines illustrate relationships proven by material clues; dashed lines correspond to relationships supposedly induced by the structural simplification of the network; the herringbone lines represent possible boundaries between human groups; the pictogram of two individuals indicates likely trade areas. The coloured areas represent the formations with silicites; colours follow the international stratigraphical chart.

rivers, the Cher, Allier, and Loire, respectively towards Berry, Sologne and the centre of the Paris Basin. In Velay, the mountains, frozen or very heavily snow-covered and long considered almost impassable barriers, were penetrated, allowing materials to be gathered and probably other interactions to occur between humans from all margins of the Massif Central (Fig. 5). Additionally, all the sites attributed to the Badegoulian in Auvergne seem to develop similar types of occupation, i.e. those of limited duration taking place during good seasons and during which various activities were undertaken. Local domains are intensively exploited, and camps are established near abundant resources found in particular places at certain times of the year; a mode of territorial management evoking that of the serial specialists of northern Canada described by L. R. Binford (1980) and taken up by F. Audouze (2007) for the Magdalenian of the

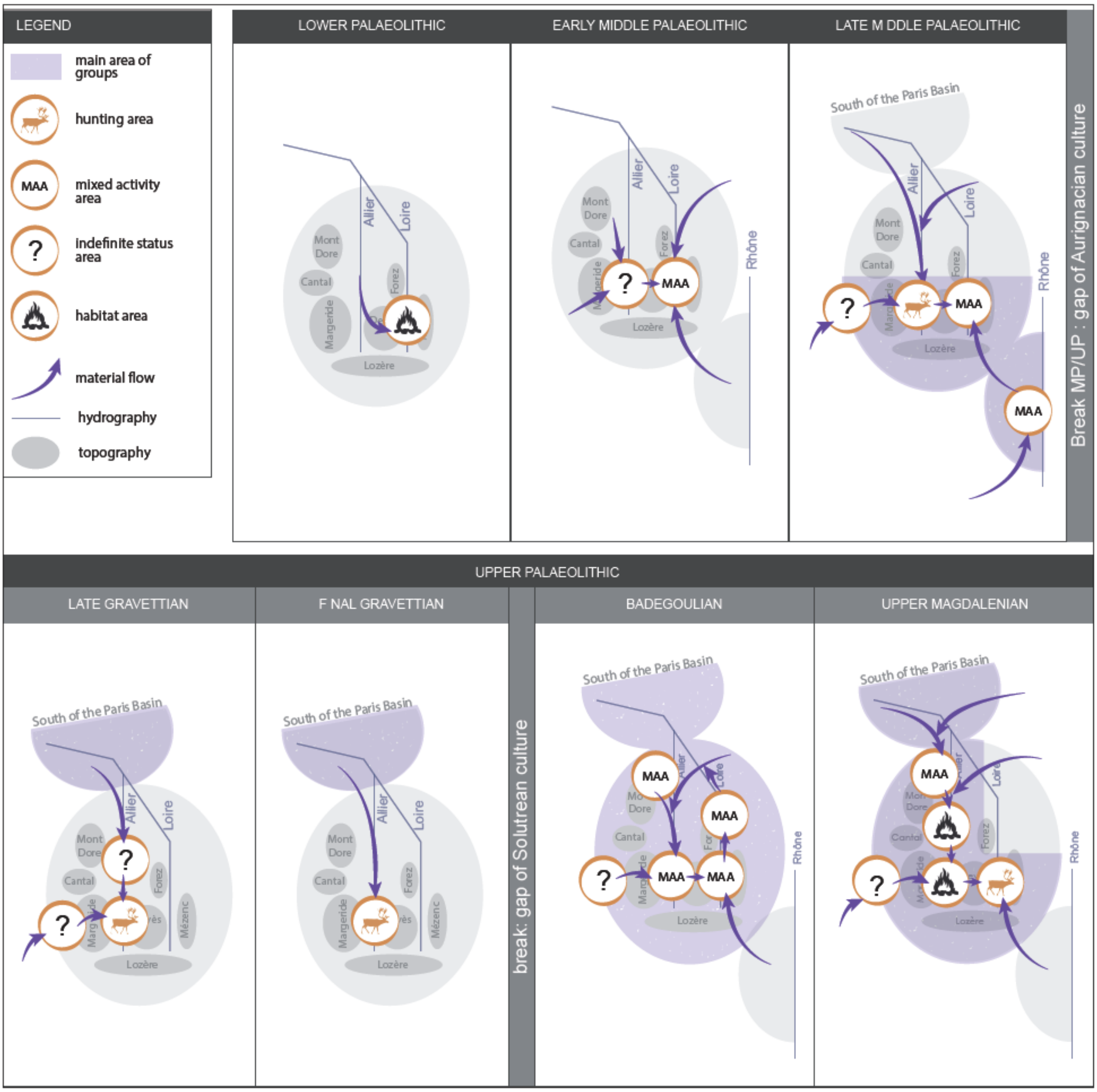

Fig. 6 – Hypothetical scheme of movement of humans in Velay in the Upper Palaeolithic deduced from the origin of raw materials.

Paris Basin. Thus, unlike during the Gravettian, the mid-mountains of Velay would no longer be frequented only on occasional expeditions, but localities became favoured places in a vast cycle of nomadism, marked out by longer and longer occupation events eventually integrating into a single territory that encompassed the southern Paris Basin and the southern part of the French Massif Central. Within this space, undoubtedly there was contact between groups from neighbouring areas for the exchange of goods and most probably individual relocations.

4. CONCLUSION

Following our investigations, the circulation patterns of prehistoric humans in Velay established in the early 1990s can be enriched, especially for the so-called 'old phase' that develops from the Gravettian to the Magdalenian (BRACCO, 1992, 1994a). This ancient phase, hitherto regarded as culturally homogeneous, seems to be divisible into two stages, one that precedes and one that follows the Solutrean occupation hiatus (Fig. 6, previous page).

The first period, that incorporates the end of the Gravettian, is fully integrated into the previous model. In it, the proportion of distantly sourced lithic raw materials, mainly from the south of the Paris Basin, is relatively high and the reason behind the occupation of the western Velay seems to be the result of temporary displacements following one mobile resource, reindeer. Thus, we speak of the migration of human groups responding to pressure from an extrinsic factor; the Velay is exploited because of the presence of the reindeer, the interest of human groups being focused on an animal resource.

During the second phase when the percentage of distantly sourced silicites decreases in favour of local and semi-local materials, the Velay is integrated into the nomadic circuit and all the environmental resources are exploited over a longer duration. The migration of human groups then occurs under the pressure of intrinsic factors and the interest of the groups becomes focussed on a multi-resource space.

In addition to providing some answers to the 30-year old debate on the origin of flint in Velay (MASSON, 1981, 1982, 1983; TORTI, 1983, 1985; DEMARS, 1985; AUBRY, 1991), this work was an opportunity to model some of the territories of the Upper Palaeolithic of Auvergne in the unprecedented form of a network of places that is more in line with the theories of ethnography and social geography. It is now possible to outline the boundary of a vast Palaeolithic province incorporating Berry and Auvergne, the spine of which is articulated around the Allier Valley. Depending on the period considered, the limits of this area expand further westwards towards Touraine or, on the contrary, contract. Nevertheless, the existence of strong links with the neighbouring provinces to the east, west and south of the Massif Central seems to be a transcendent phenomenon which makes it possible to reconsider the place of Velay in prehistoric France; a place which, until now, was considered as a dead-end evolving on the sidelines of the main prehistoric centres. Now, it can be fully integrated into the network of ideas crossing Western Europe during all of the Upper Palaeolithic.

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History of research and flint exploitation in Zelków (South Poland) – gunflint workshop – the use and meaning of flint in modern times

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Abstract

Gunflints were a commodity indispensable for the modern military, playing a key role in the arsenals of all armies. The wars in the 17th–19th centuries increased the demand for weapons, and, consequently, for significant supplies of gunflints. To have their own source of the product was a strategic objective of all governments.

Several flint workshops were located in the neighbourhoods of Cracow where flint was abundant. One of the largest and best preserved was the workshops in Zelków, a village that in the 19th century laid just on the border of Russia and Austria-Hungary. This paper discusses some issues of the mass production of gunflints in the modern era based on a case study of flint factories and the history of the Zelków workshop.

Keywords: gunflint, flint mining, history of archaeology, Zelków, South Poland, Jurassic-Cracow flint, the Multi Layered Chert Sourcing Approach (MLA).

Résumé

Les pierres à fusil étaient des pièces indispensables de l'armement militaire de l'Epoque moderne et faisaient partie intégrante des arsenaux. Les guerres des 17-19ème siècles ont considérablement accru la demande en armes à feu et par conséquent en pierres à fusil. Posséder ses propres sources d'approvisionnement fut l'un des objectifs stratégiques de tout gouvernement de l'époque.

Plusieurs ateliers de production étaient situés dans la région de Cracovie où le silex abondait. L'un des plus importants était celui de Zelków, un village situé au 19ème siècle à la frontière entre les empires austro-hongrois et russe. Cet article présente quelques aspects de la production de masse de ces pierres à fusil, basés sur l'exemple historique de l'atelier de Zelków.

Mots-clés *: pierres à fusil, extraction du silex, histoire de l'archéologie, Zelków, Petite Pologne, silex jurassique cracovien, analyses MLA.*

1. Introduction

As the Bronze Age came to its end and the Iron Age began, flint ceased to be the key material for making tools, supplanted by iron for centuries to come. Siliceous rocks lost their previous significance, but remained in use, contrary to conventional wisdom. However, the extent of that use was fairly limited indeed. It was mostly exploited locally and for domestic use. Ethnographic research proves that it was still widespread in the first decades of the 20th century.

One of the more interesting issues is the mass use of flint in modern times (17th-19th centuries) for military needs as an element of firearms (SLOTTA, 1980; KNARRSTRÖM, 2001, p. 133; GINTER, 2015, p. 287).

In Europe, small firearms came into use in the second half of the 14th century, evolving and growing in importance over time. Around the 16th century, wheel locks, and subsequently flint locks, began to be used. In early modern times, all European armies were commonly equipped with this type of weapon. Initially, France was the leading European manufacturer of gunflints (DASZKIEWICZ & TARKOWSKI 2006, p. 34–35). Significant quantities were also produced in England, which shipped them practically worldwide, especially in the 19th century (WHITTAKER, 2001; LALAK, 2006, p. 219; DE LATOUR, 2010, p. 75).

Gunflints were a commodity indispensable for the militaries of the 15th–19th centuries, playing a key role in the arsenals of all armies. The wars of the time increased the demand for weapons, and, consequently, for significant supplies of gunflints. To have their own source of the product was a strategic objective of all governments (SLOTTA, 1980, p. 352; SIEMION, 1996, p. 106). The Habsburgs, who ruled the Austrian and then Austro-Hungarian Empire, brought gunflints for their troops from regions such as Galicia, part of the Polish and Ukrainian lands annexed to the Habsburg monarchy in the late 18th century as a result of the partitioning of Poland. Gunflints for the needs of the imperial army were made from flint mined in the Jurassic deposits of the Cracow area (southern part of the Cracow-Częstochowa Upland) and around Stanislavov (now western Ukraine). Among the few flint workshops located in the neighbourhoods of Cracow one of the largest and best preserved was a workshop in Zelków (GINTER, 1992, p. 10; LALAK, 2006, p. 223; DE LATOUR, 2010, p. 84–85; GINTER, 2015, p. 288).

2. ZELKÓW – HISTORY OF THE RESEARCHES

Zelków is located at a short distance from Cracow, in the Olkusz Upland, between the Bolechowicka and Kluczwoda Valleys (Fig. 1).

Archaeologists took interest in the area of the Cracow-Częstochowa Jurassic Uplands

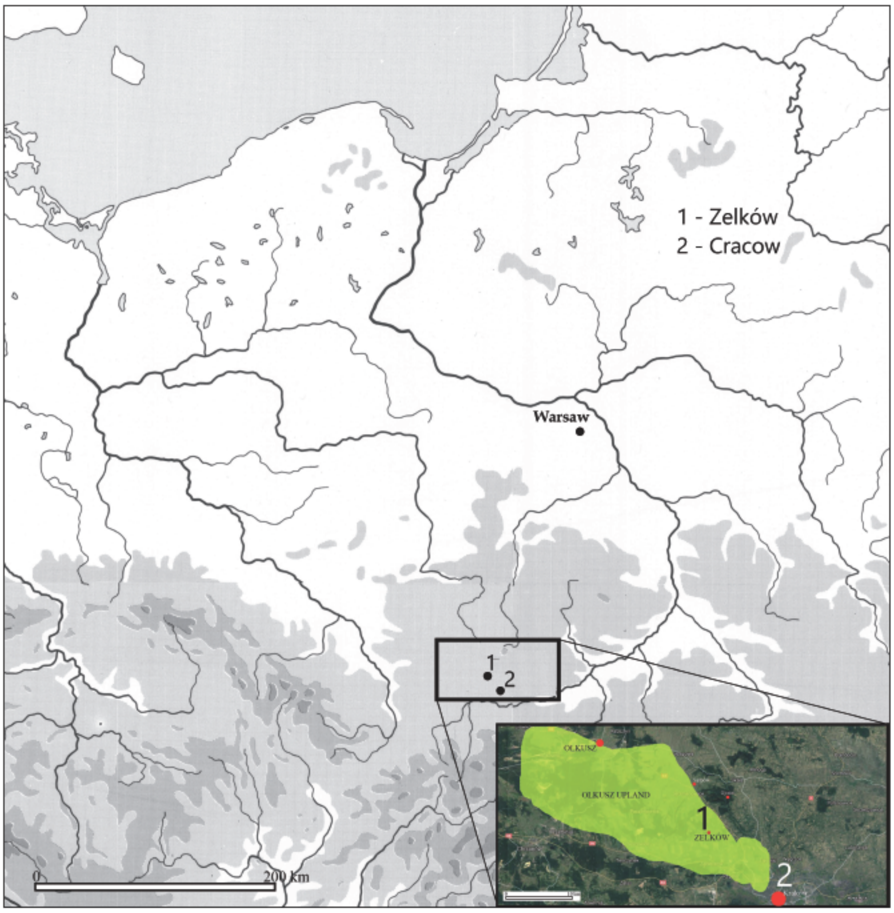

Fig. 1 – Location of Zelków, Cracow dist. Drawing: D. H. Werra. Background: GoogleMaps©.

as early as the second half of the 19th century. Important excavations were carried out in cave sites, e.g., those of Ct Jan Zawisza (1822–1886) and Gotfryd Ossowski (1835–1897). The relics they unearthed (stemming from almost all epochs and every historical period) belong presently to the collections of the Archaeological Museum in Cracow. At the turn of the 19th and 20th centuries an amateur archaeologist by the name of Stanisław Jan Czarnowski (1847–1929) also explored these territories and catalogued the caves. During the interwar period, archaeology students of Jagiellonian University set out in that direction, as well. Archaeological finds and sites were discovered in the environs surrounding Zelków, but no archaeological excavations were undertaken (LECH & PARTYKA, 2006; ZAITZ, 2009, p. 15). In Zelków itself, walk-over surveys were carried out in the years 1935–1936. They were led by a Cracovian teacher and an amateur archaeologist Albin Jura (1873–1958; TRELA-KIEFERLING, 2018).

Archived notes and documents concerning gunflint production in the neighbourhood of Cracow are very few. One note preserved in the collection of the Archaeological Museum in Cracow, written by archaeologist and conservator prof. Józef Łepkowski (1826–1894), reads: '*According to the sales assistant of the merchant Mr Fischer, in Zelków between Lipowiec and Krzeszowice, in the G[rand] D[uchy] of Crac[ow], they produce gunflint from flint to this very day*'. And further: '*In that Zelków place, even now, they still make gunflints. Cart drivers from Morawica collect them from there and carry – where to?*' (Note by J. Łepkowski, dated 1871, Archives of Archaeological Museum in Cracow). Therefore it seems that even for J. Łepkowski, already in 1871, the question of gunflint production was anachronistic and rather exotic. The search for additional archival documents dealing with the production or distribution of gunflint from Cracow's suburbs has not, as of yet, been successful. No mention of gunflint production in Zelków and its vicinity can be found in *The Geographic Vocabulary of the Polish Kingdom* – a source otherwise extensive and generous in supplying rather detailed descriptions of places in the lands of old Poland (*Słownik Geograficzny Królestwa Polskiego*, 1895, p. 565).

3. Flint materials from Zelków in the Archaeological Museum in Cracow

Preserved in the Archaeological Museum in Cracow are dozens of gunflints from Zelków (in the so-called Repository of Old Collections) as well as a large collection of flint products (in the Prehistory of Little Poland Department). Research undertaken by the authors proved that both flint collections are of different provenance. Gunflints kept at the Repository were once examined by archaeologist Stefan Krukowski (1890–1982), and they bear a handwritten label, which reads: '*Gunflints, bought, unused, from Jurassic raw material, possibly from Zelków*'. On another label S. Krukowski wrote, we find the following inscription: '*From Gloger collection, no n[umber]*, "*place unknown*", "*selection of gunflints from raw material as in Zelków*"'. The oldest label contains the information: '*Gloger collection. No? Place of origin unknown*'. S. Krukowski assumed, as it seems, that the gunflints came from the collection of Zygmunt Gloger (1845–1910), a collector, amateur archaeologist, historian, traveller, ethnographer, and prehistorian. His collection was transported to the Archaeological Museum of the Polish Academy of Arts and Sciences (presently: The Archaeological Museum in Cracow), pursuant to his final will and testament. The collection (nine chests with artefacts; above all, flint tools from various areas of Poland) was transported to Cracow in 1912 (CHOCHOROWSKA, 1990, p. 217; WOŹNY, 2009, p. 160). Gloger was interested in gunflints. In his *Old Polish Encyclopaedia* (*Encyklopedia Staropolska*) he wrote: '*Gunflint for guns, used before introducing pistons and needle guns, were produced in factories existing since long ago in Cracow vicinity and also in a factory founded at the end of 18th century in Niżniów, Stanisławowskie voivodship, in Galicia. The latter factory, owned by Freudenheim, employed several dozen workers. Gunflints produced near Krzemieniec in Volhynia, even at the time when domestically they were out of use, were purchased in large numbers and exported to Asia*' (GLOGER, 1903, p. 237). But today we cannot claim with certainty that the gunflints kept at the Archaeological Museum in Cracow were actually collected by Z. Gloger himself. Ten gunflints from this collection were investigated according to the Multi Layered Chert Sourcing Approach (in short MLA; BRANDL, 2016) in order to test if the raw material corresponds to Jurassic Cracow flint or if a different source has to be assumed.

A much larger assemblage of flint material from Zelków (22 boxes), retained in the Archaeological Museum in Cracow, comes from the previously mentioned walk-over surveys of A. Jura. All this material was purchased by the Archaeological Museum in 1960 (TRELA-KIEFERLING, 2018). The gunflint workshop in Zelków was located only a kilometre away from the Neolithic site in Bębło (KOWALSKI & KOZŁOWSKI, 1958). A. Jura, unfamiliar with the issues of gunflint production, mistakenly assumed that they were the remains of a Neolithic workshop/mine (A. Jura, Field notebook No 2, note from 1954, Archaeological Museum in Cracow, Prehistory of Little Poland Department, p. 315).

Proper dating of the site in Zelków can be attributed to the research of Stanisław Kowalski and Bolesław Ginter. In 1964, they published an article that included information acquired from local inhabitants. At that time, B. Ginter and S. Kowalski wrote that one could still find residents familiar with the history of local gunflint production. According to their sources, gunflint production in Zelków ceased around 1880, but it is possible that production toward the end of this period focused on flint for firestrikers ('strike-a-light' tools), rather than gunflints (GINTER & KOWALSKI, 1964, p. 84; for a different view cf. LALAK, 2006, p. 223). Site walk-over surveys and interviews conducted in Zelków by B. Ginter and S. Kowalski helped to uncover the true character of the site and, above all, to determine its chronology.

4. GUNFLINT WORKSHOPS IN THE AREA OF THE CRACOW UPLAND

Gunflint workshops were located near Cracow in large numbers due to the natural occurrence of flint in residual clay soil. Interestingly, they were often located near the remnants of Neolithic mine workshops, which used the same source of raw material (GINTER & KOWALSKI, 1964, p. 83).

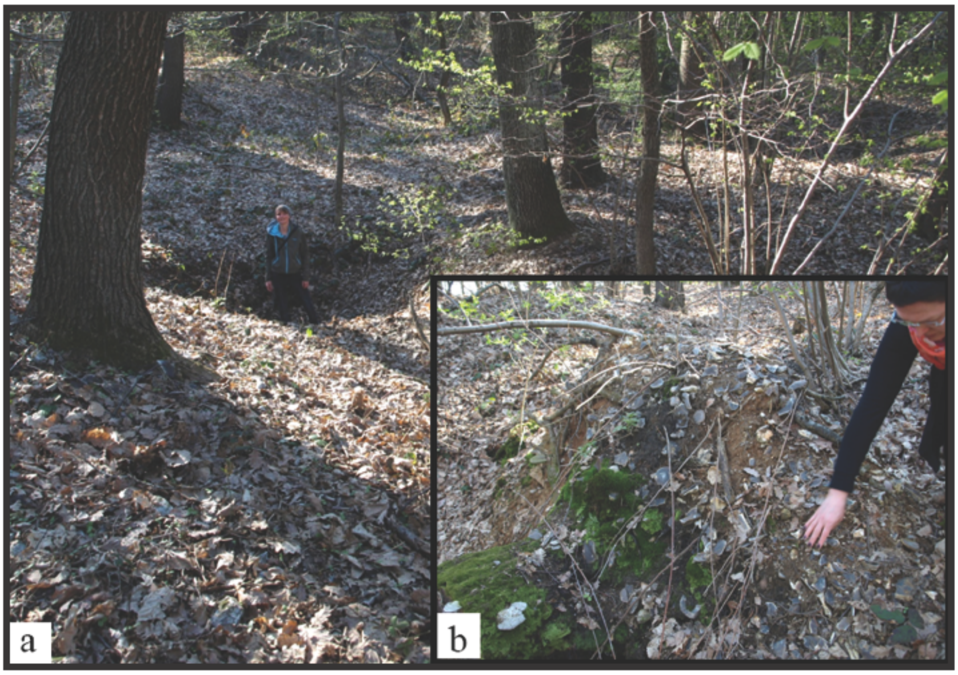

Fig. 2 – Zelków, Cracow dist. Modern flint-mining site; a - Characteristic landscape; b - Flint material accumulated on the surface of the site. Photo: M. Woźny and D.H. Werra.

The first mentions of firearms in Europe come from the 14th century. Handheld firearms appeared a little later, in the second half of the 14th century. The flintlock firearm was in use as a military weapon until about the mid-19th century and only exceptionally in the second half of the 19th century. As a hunting weapon (often used for poaching), it was still in use until the beginning of the 20th century. Moreover, gunflints or other similar implements were used at the end of the 19th century as 'strike-a-light'. Flint in Zelków was extracted by the opencast method. Traces of this extraction method are still visible on the site in Zelków today – as craters and remnants of excavation pits (Fig. 2). Even now we find numerous flint flakes on the slag heaps surrounding the pits. These are the production wastes (Fig. 2). But we find no gunflints there, since these were most probably produced away from the mining field (LALAK, 2006, p. 238-239). Iron tools, such as hammers with a sharp point and a small anvil, were used for gunflint manufacturing (GINTER & KOWALSKI, 1964, p. 83-84; SLOTTA, 1980, p. 355; WOODALL & CHELIDONLO, 2006, p. 222; DE LATOUR, 2010, p. 82). This is indicated by ferruginous points preserved on the surface of cores and semi-finished products; these are traces left after percussion with a metal tool.

Gunflints were manufactured primarily by the rural population living in the vicinity of flint outcrops. There were also specialised workshops located in city suburbs and, sporadically, workshops by weapon factories. The production was chiefly for military purposes and later also for household use. A particular weapon required a gunflint of appropriate size. Therefore, their production was constrained to standardised morphometric, typological and stylistic traits (LALAK, 2006, p. 239; GINTER, 2015, p. 288).

5. PRIMARY RESULTS OF ANALYSIS OF FLINT MATERIAL FORM ZELKÓW

As previously mentioned, the collection of the Archeological Museum in Cracow contains flint material gathered by A. Jura. The material under analysis, with its share of particular morphological groups, is therefore a result of the selection made by the researcher during his visits to the site during the years 1935–1936.

We may assume that the first stage of selection and preparation of raw material for further processing by the gunflint producers was very similar to the one in prehistory (cf. DZIEDUSZYCKA-MACHNIKOWA & LECH, 1976). In the analysed part of the collection only two fragments of flint concretions were found, as well as two nodules with traces of singular percussions and one pre-core. This does not mean, however, that their presence at the site was rare; on the contrary, during inspection of the site, the authors found that material of this type is preponderant (next to flakes and wastes; Fig. 2).

This may indicate that the first stage of work on the site included introductory processing, aimed at choosing blocks suitable for further work. The quality of raw material was examined by detaching singular flakes. Material containing fissures and flaws in the flint matrix was discarded (DZIEDUSZYCKA-MACHNIKOWA & LECH, 1976, p. 117). However, no further steps were performed to give the nodule an appropriate shape. No edge or back preparation was done, nor were the cores rejuvenated (see GINTER, 2015, p. 288). This is confirmed by the lack of characteristic percussion marks on the analysed cores and the absence of preparation or repair flakes such as crested blades and rejuvenation flakes. Core preparation was confined to shaping the platform by singular percussion, although in many cases natural surfaces were adapted for platforms (cf. LALAK, 2006, p. 225; WOODALL & CHELIDONLO, 2006, p. 223). The selected cores are mostly single platform flake cores. Singular blade-flake specimens and double platform flake cores were also found. The platforms are oriented at acute to extremely acute angles in relation to the flaking face. Most of the cores are residual forms, exploited almost to the end (GINTER & KOWALSKI, 1964, p. 85). The forms under analysis are small specimens, from 68 to 120 mm in diameter. Semi-finished products obtained from them for gunflint production had maximally 76 mm in length and 59 mm in width, whereas the smallest could have been some 45 mm long and 23 mm wide (Fig. 3: c-f, g).

S. Kowalski and B. Ginter, in their first work on flint material from Zelków, pointed to the characteristic feature of the cores: traces of strong, smashing percussions visible on the platform. At the same time, the researchers recorded the presence of cores which were nearly identical in shape and character to cores known from prehistoric sites (GINTER & KOWALSKI, 1964, p. 85).

Flakes, blades (although the latter ones are less numerous) and associated fragments make up the majority of material listed in significant amounts in gunflint inventories (Fig. 3: a, b, g, j). Due to the fact that gunflint production involved the use of only selected flakes and blades, the remaining specimens were left on the site as waste.

Complete blades recorded are predominantly without traces of cortex, though some are partially cortical. Two types of butt-shapes were found: large plane butts and linear butts. The largest blade recorded has a length of 90 mm, a width of 16 mm and is 5 mm thick. The average weight of the blades amounts to 8.42 g.

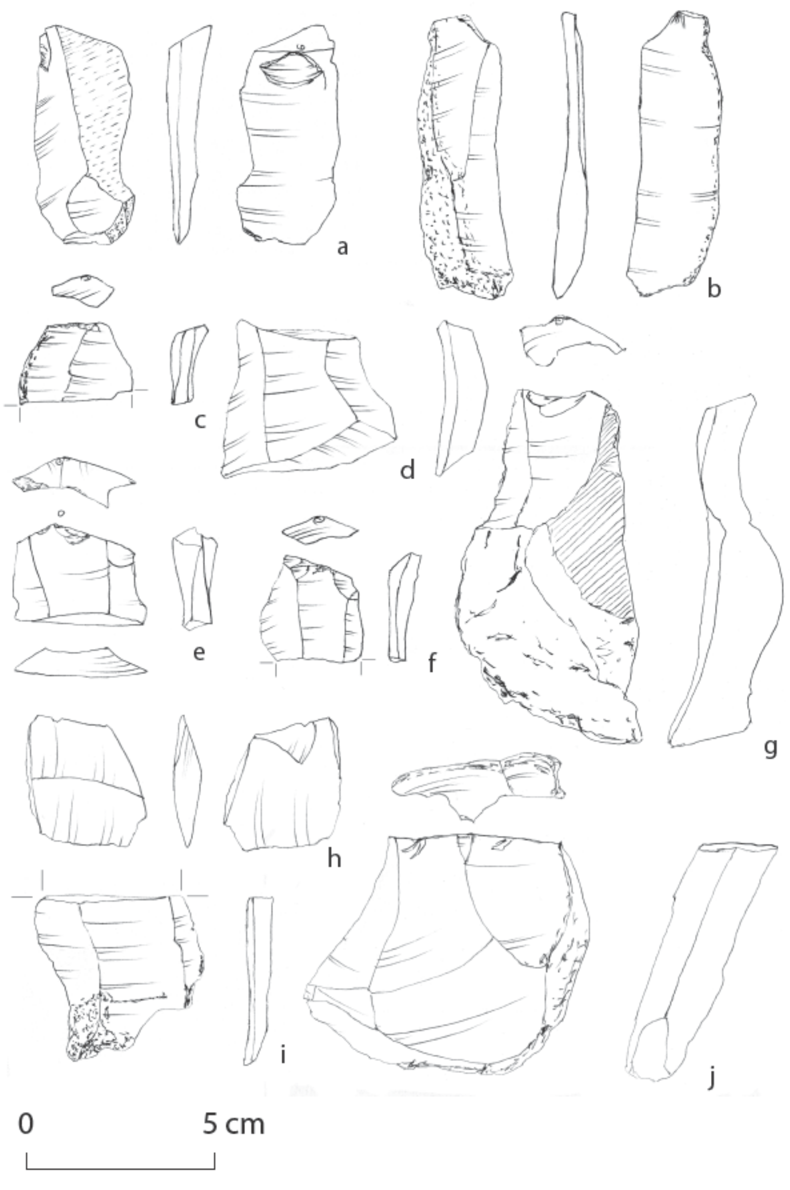

Fig. 3 – Zelków, Cracow dist. Flint materials:
a–b, g: blades; c–f, h, i: gunflint products and production waste; j: flake. Drawing: D.H. Werra.

Flakes are a similar case. Most numerous are reduction flakes (266 specimens) and flakes without cortex (254 specimens), while the number of cortex flakes is comparatively low (only 31 specimens). In terms of size, specimens with a diameter of up to 80 mm are the most common; they make up 499 of 551 flakes, of which 160 specimens have a diameter of less than 50 mm. A minority of flakes measures over 80 mm in diameter—only 52 specimens.

The butts of the analysed flakes are primarily prepared, formed by singular scars (485 specimens). Only 41 specimens have unprepared butts, and 25 have punctiform butts (cf. GINTER, 2015, p. 292). With regard to form, large oval or rhomboid butts are predominant (66.45 %). Butts of the wing (18.3 %) and triangular (15.2 %) types were also present.

Our attention is drawn to the fact that almost all specimens have a strongly obtuse angle between the butt surface and the inverse side of the blank (Fig. 3: a, b, g). The butts are often concave with characteristic deflection upwards and are often placed diagonally to the axis of the specimen (Fig. 3: b). The bulb is large and wide, often with fissures, which indicates percussion with a hard hammerstone (MIGAL, 2005) – in this particular case, possibly a metal hammer (GINTER & KOWALSKI, 1964, p. 85; LALAK, 2006, p. 228; WOODALL & CHELIDONLO, 2006, p. 223).

A small number of tools was selected from the collection under analysis: one endscraper, one bifacial axe as well as semi-finished gunflint products and production waste (Fig. 3: c-f, h, i). The chunky endscraper was made on a partially cortical flake with a high circular front. The specimen's weight is 18.37 g. The bifacial axe bears traces of original polishing and signs of later remodelling. This particular piece has numerous crushed areas, which are most probably the result of using the axe as a hammerstone in the last phase of its exploitation. The specimen's weight is 98.44 g. Thirty-four blade fragments with a broken distal end and 32 flake fragments (cumulative weight: 180.43 g) with broken butt-parts and/ or distal ends were also selected (Fig. 3: c, f, i). These are mostly specimens without cortex. Only singular pieces came from blank preparation. Their lengths are between 15 and 61 mm, while their widths vary between 21 and 51 mm and thickness between 4 and 13 mm. Due to their distinctive presence in the analysed sample, it was assumed that they should be related to the early stages of gunflint preparation. However, they do not have the characteristic fractures which occur during segmentation on a hard anvil (see GINTER, 2015, p. 292 and Tabl. VII: 3–6; VIII: 1–8). Gunflints themselves were not recorded in the analysed part of the collection.

6. GUNFLINT PROVENANCE STUDIES

For provenance studies, ten gunflints housed at the Archaeological Museum in Cracow were analysed. The MLA chert sourcing technique combines visual, microscopic and geochemical methods and was successfully tested during several pilot studies (BRANDL *et al.*, 2011, 2014, 2016; MOREAU *et al.*, 2016). Based on the knowledge of raw materials used in major European gunflint production centres, it was safe to assume that the raw material of the investigated specimens either derived from the Cracow area or from the most important source at the time, Meusnes in the Loir-et-Cher Department in France. Hence, our investigations concentrated on those two possibilities for a provenance of the assemblage.

6.1. Geological samples

6.1.1. Meusnes flint

This raw material, which is also commonly known as '*Silex blond du Berry*', is of Upper Cretaceous (Turonian) age. It possesses a honey-brown and sometimes greyish coloration, the rock matrix is in many cases semitranslucent. The most characteristic visual features are large, irregularly shaped white non-translucent intraclasts. Microscopically, large bioclasts (e.g. molluscs, bryozoa, fish vertebrae) and foraminifera dominate the microfaunal assemblage (AFFOLTER, 2002, p. 132).

6.1.2. Jurassic Cracow flint

Silicites from the larger surroundings of Cracow are of Upper Jurassic (Mid Upper

Oxfordian-Lower Kimmeridgian) age bound to geological formations of the Crakow-Częstochowa Upland. By tendency, the material appears more heterogeneous than Meusnes flint, however rock parts can be very homogeneous, and intraclasts similar to material from Meusnes can also be present. Sediments in this particular geological zone display typical elements of a sponge megafacies limestone, i.e. large bioclasts which are in many cases visible to the naked eye. These include sponge remains in associations with forams, and – rarer – radiolarians (e.g. FRAAIJE *et al.*, 2012).

From the Cracow area, four sites were chosen for sampling: Mników, a secured procurement site for gunflint production, Sąspów, an important Neolithic quarrying area, Będło and Czajowice, both extensively used since prehistoric times for raw material exploitation. More detailed references to those sites are provided by B. Ginter & S. Kowalski (1964), and J. Lech (2003).

Despite those differences, Meusnes and Cracow raw materials can be visually very alike and macroscopically not well distinguishable. If the fossil content is additionally very scarce, microscopic analysis can also produce ambiguous results.

6.2. Archaeological material

Visually, the investigated gunflints display a yellowish-brown to light grey colour range, in most cases with characteristic white intraclasts in a semitranslucent matrix. Microscopic analyses indicate a Cretaceous rather than Jurassic age, however, trace fossil inclusions are scarce and not sufficiently informative for a secure assignment. Hence, geochemistry promised the greatest potential for provenance studies.

6.3. Geochemical analysis

Trace element concentrations were investigated through Laser Ablation Inductively Coupled Mass Spectrometry (LA-ICP-MS). The laser unit comprises an Agilent 7500 and ESI NWR-193 and is located at the Central Lab for Water, Minerals and Rocks, NAWI Graz, University of Graz and Graz University of Technology. Ablation was performed using a 193 nm laser pulsed at 5-10 Hz with 30 mm spot size and laser power corresponding to ca. 7 J/cm^2. Helium was used as carrier gas. Data was acquired in time resolved analysis mode. Standard glasses NIST 612 and NIST 610 were routinely analysed for standardisation and drift correction, NIST 614 was analysed as unknown and allowed for replication within 10 % relative error. Silicon (Si29) was used for internal standard correction. Raw data were calculated with GLITTER-software. Detection limit is typically 0.1 ppm, however values below 1 ppm display a significantly higher error.

A representative number of geological samples, 2 x 2 mm in size, were imbedded into resin mounts and polished for analysis. For geological reference material, 88 samples from the four sources of Jurassic Cracow 'flint' and 25 samples from Meusnes in France were used. The gunflints were analysed in a non-destructive manner (Fig. 4), however only data from eight specimens were suitable for this study. Gunflint samples 2 and 9 produced erroneous values and were therefore excluded. Effects of surface alteration (patina) are handled by discarding the first few seconds of the signal, a procedure successfully applied in previous studies (e.g. MOREAU *et al.*, 2016).

In order to control and minimise effect of heterogeneities in silicite samples, three distinct spots were measured at each geological sample, and four in the case of the archaeological material. Concentrations of 48 trace elements were recorded in the course of 348 single measurements for geological samples and 32 for the gunflints.

6.4. Results

The results of this geochemical study reveal that trace elements germanium (Ge) in combination with other High Field Strength Elements (HFSE) such as aluminium (Al), titanium (Ti) and barium (Ba) are best suitable for a differentiation between material from Meusnes and sources around Cracow. These elements are typically immobile and able to replace silicon (Si) cations in the crystal lattice of chert and flint. Within distinct depositional environments the

Fig. 4 – Mount for LA-ICP-MS analysis containing the sample of investigated gunflints. Photo: M. Brandl.

distribution of such elements can be considered source specific, hence they can be used for provenance investigations. When graphically plotted together, it becomes apparent that the investigated gunflints altogether cluster in the Meusnes data field (Fig. 5 and Fig. 6).

The geochemical results are in agreement with the fact that the scarce microfossil content corresponds best with Cretaceous marine silicites. Accordingly, we conclude that the investigated gunflint assemblage originated from the area of Meusnes in France, and not from a source in the vicinity of Cracow.

7. SUMMARY AND DISCUSSION

In technological terms, gunflint production consisted of the same stages as prehistoric flint manufacturing. This was above all due to the character of the flint material itself. The same techniques were applied, such as breaking or retouching during the final shaping of gunflint. The end result of production in Zelków was a semi-finished product (a flake or a blade), which could be used for further manufacturing of gunflint. The distinctive feature of gunflint manufacturing is the application of metal tools (LALAK, 2006, p. 239). The geochemical investigation of finished gunflints from the Archaeological Museum in Cracow however did not produce evidence for material from sources in the vicinity of Cracow. Hence it has to be assumed that Z. Gloger, who showed interest in the subject, acquired the assemblage from an unknown source. He probably bought the pieces or they were presented to him as a present. Krukowski's assessment that the raw material derived '*possibly from Zelków*' illustrates the problem of solely visual raw material determination in general.

Flint production had to fulfil specific morphometric, typological and stylistic requirements imposed by the standards of the gunflint 'industry' (LALAK, 2006, p. 239; GINTER, 2015, p. 288). This was conditioned by the fact that a particular weapon needed gunflint of a specific size. It was for this reason that on the site in Zelków we found regular blades and flakes of very good quality, which were nevertheless rejected by the gunflint maker (GINTER & KOWALSKI, 1964, p. 85).

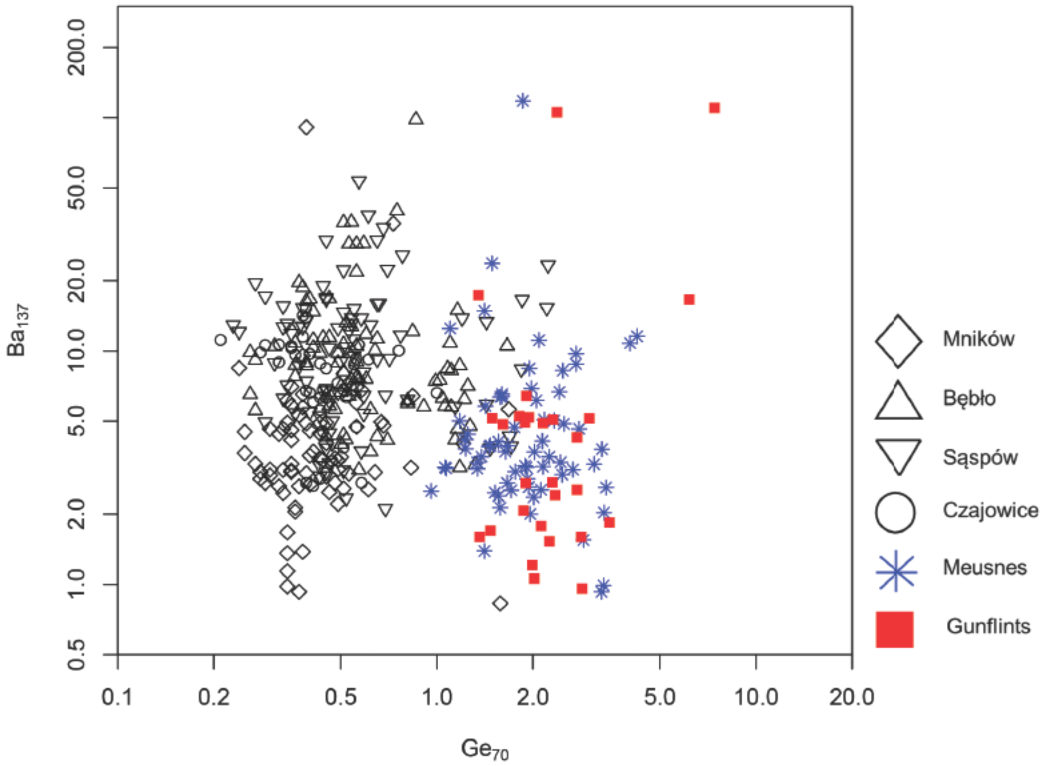

Fig. 5 – Bivariate Ge versus Ba scatter plot of the investigated samples. Graph: M. Brandl.

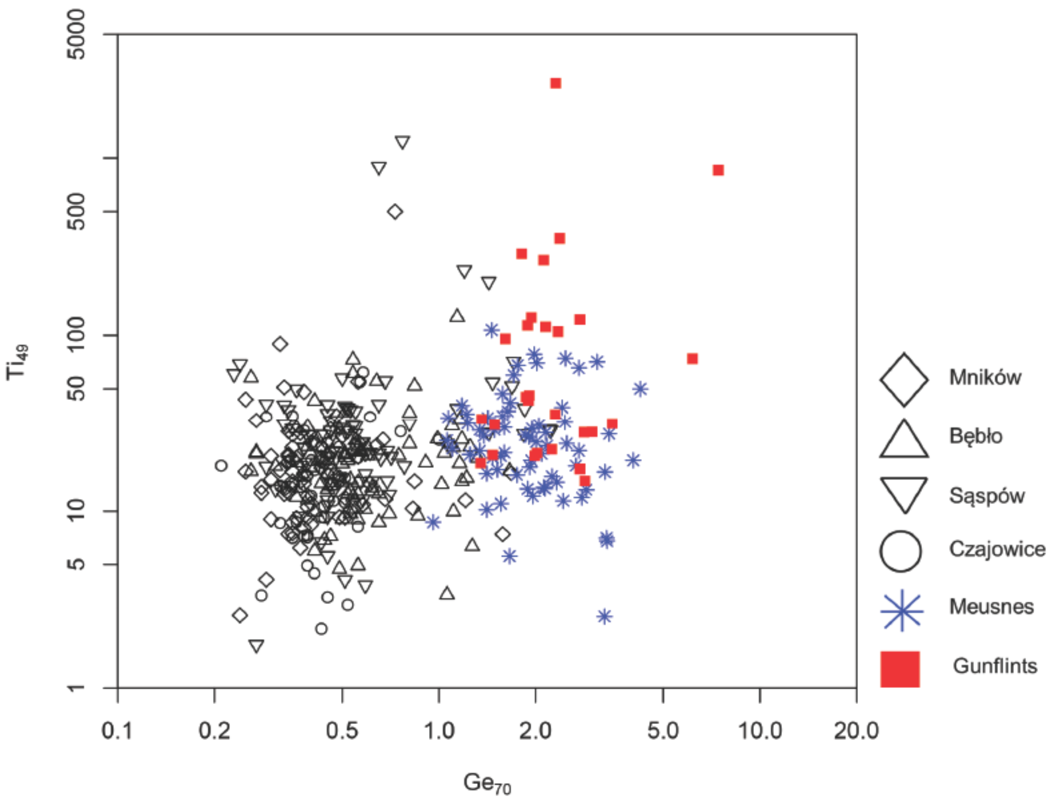

Fig. 6 – Bivariate Ge versus Ti scatter plot of the investigated samples. Graph: M. Brandl.

The lack of information in written sources on flint mining in Zelków for the needs of gunflint production is no exceptional situation. Details of gunflint production were kept secret by the military, and leaks of any confidential information on this topic were punishable by death (DE LATOUR, 2010, p. 80; LIBERA, 2015). The heyday of gunflint production lasted until the beginning of the 19th century – that is, until the moment when around 1820 the percussion lock for firearms was invented. In this historical background, gunflint production in Zelków takes an exceptional place; according to Łepkowski's note, gunflint was still produced near Cracow as late as 1871, whereas Ginter and Kowalski consider 1880 as the final year of gunflint manufacture (GINTER & KOWALSKI, 1964, p. 84).

Gunflint, a small object of flint, was for two and a half centuries an indispensable part of military equipment. The effectiveness of a soldier in action depended on the quality of its workmanship. The use of guns equipped with flintlock was ubiquitous and the scale of its production enormous. Therefore, it is worthy of particular attention.

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Placing the transmission of technical knowledge in the system of blade production. A case study from the Early Neolithic flint mine of Casa Montero (Madrid, Spain)

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Abstract

Casa Montero has provided key information to understand the earliest Neolithic technical system of lithic production at the flint mine. This is a result of a complex network of seven different operational sequences. They were all successfully harmonised in order to allow the performance of other sequences. This organisational knowledge was a substantive part of the social capital of Early Neolithic communities and, as such, required of its inter-generational transmission.

Both the aging process and the continental nature of Casa Montero's flint limited the efficiency of blade production. As a result, most of the extracted raw material was discarded throughout the process. However, a resourcefully planned management allowed its reuse for other socially critical purposes such as learning how to knap.

The relation between blade production and the learning of knapping happens by impeding the competition between both sequences over raw material and by encouraging the apprentice´s motivation.

Keywords: Early Neolithic, Casa Montero, flint mining, knowledge transmission, blade production.

Résumé

Casa Montero a fourni des informations clés pour comprendre le premier système technique néolithique de production lithique au sein de la minière à silex. Le résultat est un réseau complexe de sept séquences opérationnelles différentes, qui ont toutes été harmonisées avec succès afin de permettre la réalisation d'autres séquences. Ce savoir organisationnel était une partie substantielle du capital social des communautés du Néolithique ancien et, en tant que tel, exigeait sa transmission intergénérationnelle.

Le processus de recristallisation du silex de Casa Montero et sa formation continentale ont limité l'efficacité de la production laminaire. En conséquence, la plupart de la matière première extraite a été rejetée tout au long du processus. Cependant, une gestion planifiée de manière efficace a permis de la réutiliser pour d'autres fins socialement critiques, tels que l'apprentissage de la taille.

La relation entre la production laminaire et l'apprentissage de la taille passe par éviter la concurrence entre les deux séquences opératoires basée sur la matière première et par l'encouragement de la motivation chez les apprentis.

Mots-clés : *Néolithique Ancien, Casa Montero, minière à silex, transmission des connaissances, production laminaire.*

1. Introduction

The work in a Neolithic flint mine is a complex phenomenon that implies a variety of factors, ranging from economic tasks to social interactions. One of the most interesting questions postulated by modern research, is how work among miners was managed and organised: whether they were under control of small specialised groups (BOSTYN & LANCHON, 1992, p. 221) or, on the contrary, it was a manifestation of communal effort in which all the members of a group or aggregation of groups worked together (DÍAZ-DEL-RÍO & CONSUEGRA, 2011, p. 228). Despite the fact that most European flint mines can, in general, present different forms of exploitation and management, throughout a spacious chronological period between the Neolithic and the Bronze Age, we can conclude that all of them are the result of collective work that could involve from small groups of people to much larger eventual aggregations.

The Neolithic exploitation of Casa Montero (Madrid, Spain) belongs to this last group. Recent investigations reveal that the work in this mine was carried out during different mining events that were produced by important concentrations of groups at a certain time (5400-5200 cal BC) and place (interior of the Iberian Peninsula), during which the density of the regional population was very low, and human groups relatively small and mobile (DÍAZ-DEL-RÍO & CONSUEGRA, 2011).

The concentration of people under such circumstances would require an efficient organisation and planning of tasks to avoid conflict. A mining event would include a series of processes, such as the extraction of the raw material, the management of the extracted flint, comprising both production and management of the residues that were generated, as well as the distribution of the final products. But furthermore,

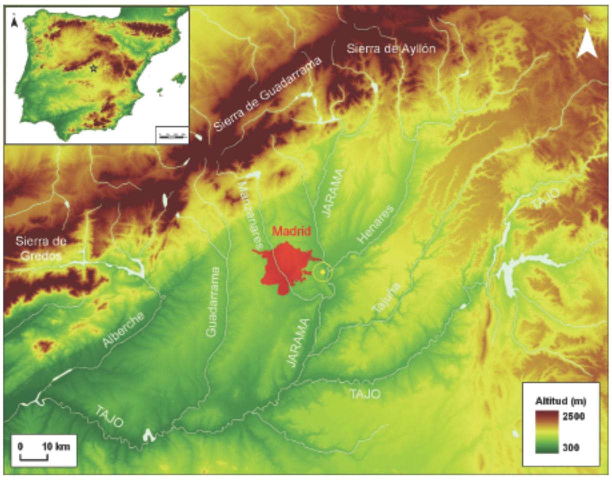

Fig. 1 – Location of Casa Montero Flint mine.
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(CONSUEGRA & DÍAZ-DEL-RÍO, 2015, p. 407, fig. 1).

other endeavours would take place, such as subsistence tasks and social or even symbolical interactions (CONSUEGRA *et al.*, 2018).

The objective of this paper is to analyse in which manner a social task, such as the transmission of knowledge of flint knapping to the next generation, was interrelated with the other tasks that were being carried out at the mine of Casa Montero, mainly the production of blades, which it competed against for the use of raw material. Both tasks had to be possible, compatible and simultaneously harmonic to guarantee the whole technical system and that the individuals in the phase of apprenticeship could be completely integrated within the group and the community.

2. CASA MONTERO: AN EARLY NEOLITHIC FLINT MINE

Casa Montero was a flint mine located in the centre of the Iberian Peninsula, in one of the elevated moors next to the convergence of the Jarama and Henares rivers (Fig. 1). The region is well known for its abundance of siliceous material that was exploited since the Lower Palaeolithic. Until the discovery of Casa Montero in 2003, no Prehistoric flint-related mining or quarry works had been identified in the area, though some related to certain historical periods had been.

Furthermore, it was the first Neolithic flint mine to be confirmed and excavated in the Iberian Peninsula (CONSUEGRA *et al.*, 2004). Its discovery and further study bolstered investigation regarding Neolithic mining -until then represented by the works of La Venta (RAMOS MILLÁN *et al.*, 1997) and the variscite mines of Can Tintorer (Gavà, Spain) (for example CAMPRUBÍ *et al.*, 2003)- with the incorporation of new and interesting contributions (for example ODRIOZOLA & VILLALOBOS-GARCÍA, 2015; TARRIÑO *et al.*, 2014). The research project, carried out by the *Consejo Superior de Investigaciones Científicas* (CSIC) between 2006 and 2011, has contributed abundant information regarding a chronological period with almost no representation in the interior of the Iberian Peninsula.

Within the intervened sector of 4 ha, 3794 Neolithic flint mining shafts were documented (Fig. 2). These shafts were, in general, deep and narrow, dug in vertical piercing the three upper episodes of silification documented in the geological formation of the area. Presenting a circular shape, with certain variations of the section, these structures re-adapt to the disposition of the siliceous episodes affected by the collapse of lower evaporitic strata. They present an average diameter of 1.12 m and a depth that varies from 0.98 m to 9.26 m. The separation of the shafts located in a large concentration (CAPOTE *et al.*, 2008; CONSUEGRA *et al.*, 2004) varies from 1.38 m to scarcely a few centimetres (0.04 m), and in some occasions the entrances of some shafts are in direct contact.

The process of excavation of the shafts was perfectly organised to avoid possible accidents or collapses (CAPOTE *et al.*, 2008). After having excavated the structure and having extracted the flint, they were filled in with sediment, knapping waste and other elements, until they were refilled almost completely.

The refitting of artefacts that represent a minority in the general assemblage, such as ceramics and quartzite percussion tools, proves that groups of 6 to 22 shafts were opened at the same time, organised in different mining events (CAPOTE, 2011, p. 238). On the other hand, the chronology obtained by radiocarbon dating indicates that the exploitation of the mine barely lasted 100 years, between 5337 and 5218 cal BC at 1sigma (DÍAZ-DEL-RÍO & CONSUEGRA, 2011, p. 226).

These results are surprising if we take into consideration the scarce data related to the Neolithic in the Community of Madrid (DÍAZ-DEL-RÍO & CONSUEGRA, 2011, p. 228), which indicates that during this period the population consisted in small groups dispersed throughout the territory, whose economy was based on agriculture and pastoralism (DÍAZ-DEL-RIO *et al.*, 2011, p. 119). Therefore, to be able to carry out a task with the dimensions as the one documented at Casa Montero must have necessarily required an aggregation of different groups in the region that would have probably had to travel many kilometres to the mine.

In this context, the mine would not only secure the function of obtaining flint, but was also the place for other social interactions (DÍAZ-DEL-RÍO *et al.*, 2011). Some of the characteristics of the mining structures, as well as the documentation of other non-extractive activities and maintenance tasks at the mine, seem to indicate the participation of the totality of the group in the mining experience, including different groups of age and sex.

3. The role of mines and provisioning sources in the process of knapping apprenticeship

The reduction process of siliceous rocks is the result of the implementation of a complex network of know-how of diverse nature: abstract knowledge, mental images and motor experience (APEL, 2008, p. 99). Therefore, to learn how to knap requires more than just the correct and precise execution of gestures to extract rock fragments, including knowing how to manage the volume of the rock, abstractly fix the shape of the final product, anticipate shape changes with each removal (HOVERS, 2009, p. 12; NONAKA *et al.*, 2010, p. 157), plan the expected productivity and repair eventual errors or accidents that may occur during the knapping process. To obtain all this know-how it is necessary to include the apprenticeship of all the aspects of the c*haîne opératoire*: the obtaining and selection of the appropriate nodules (BARKAI & GOPHER, 2013, p. 130; STOUT, 2002, p. 696) in shape, size and quality; the management of the residues that are generated during knapping, recycling, reuse or reconfiguration; and, of course, the eventual hafting, use and maintenance of the final tool (BARKAI & GOPHER, 2013, p. 130).

An individual belonging to a Neolithic community would have been exposed to a phase of impregnation (for example BAMFORTH & FINLAY, 2008; NISHIAKI, 2013, p. 179), in which the person would have observed how different members of the group would have made and used different stone tools. Nonetheless, the person may not have always been in contact with the initial processes of the work that were carried out at the siliceous outcrops, quarries or mines. Furthermore, in the places of the final use of the lithic objects, there are no reserves of raw material with which one could practice the fabrication of a tool, since only the material that was going to be used, in general, was transported. Therefore, if the individual did not go to the place of extraction, all that part of know-how of the process would be foreign to that person.

Due to all these reasons, the sources of supply of lithic materials would be the ideal places to acquire the knowledge of the complete work process. In these areas, were raw material was abundant (for example AUDOUZE & CATTIN, 2011; MILNE, 2012, p. 119), the first phases of extraction and selection were carried out, and there were enough and appropriate resources to practice knapping techniques.

Furthermore, in general, these places were located at a certain distance from the living spaces, which adds the experience of the journey (MILNE, 2012, p. 120, 138-140), the better recognition of the territory that they frequent, and the estimate of the needs that may appear during the trip without the supporting resources that are offered by their usual settlement. In enclaves where collective work was carried out, such as in mines and, namely in Casa Montero (DÍAZ-DEL-RÍO & CONSUEGRA, 2011, p. 228), the apprenticeship of an individual also included meeting members of other groups and cooperating with them. Therefore, mines were

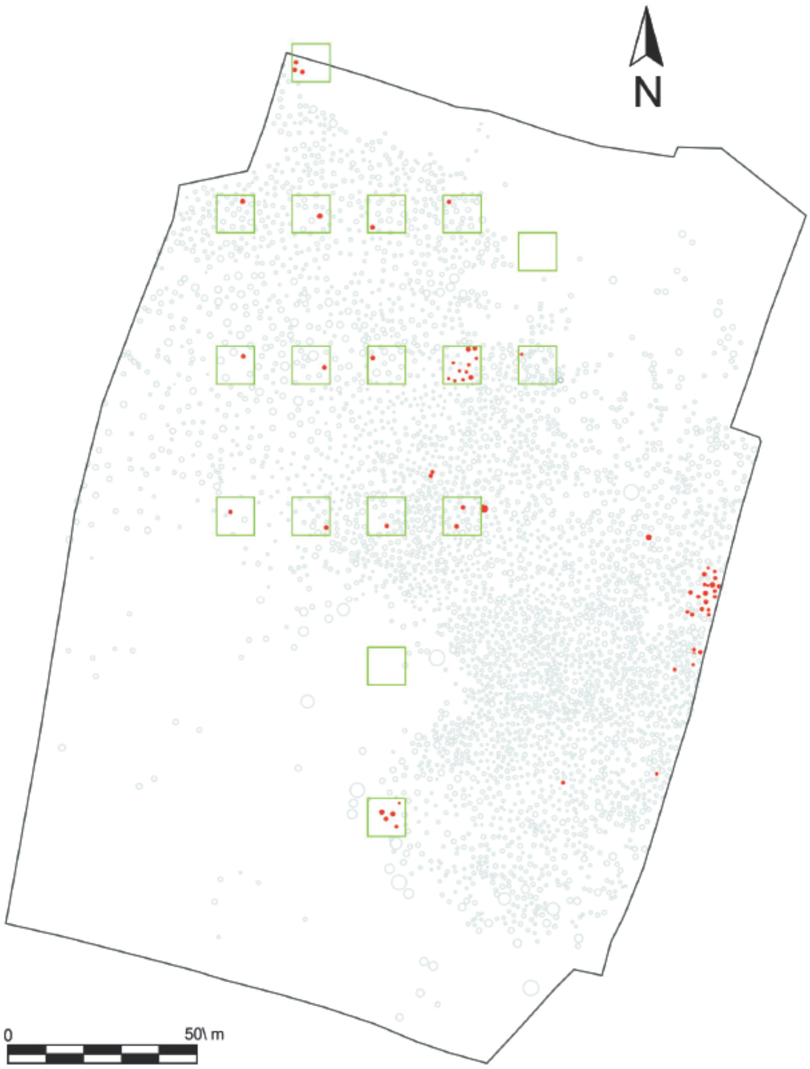

Fig. 2 – Casa Montero flint mine. The shafts analysed are coloured in red © Casa Montero project.

ideal places for technical, social and individual education that could be understood as part of an initiation for the youngest members.

The recent research carried out at Casa Montero has offered interesting results regarding the evidence of knapping apprenticeship that was carried out at the mine (CASTAÑEDA, 2018). Given the demographic parameters that are known for the Interior of the Iberian Peninsula during the Early Neolithic, being scarcely populated with a high dispersion of small, mobile groups, with a low life expectancy, we must understand that the transmission of knowledge had a critical importance to secure the continuity of the way of life of a group, including its own survival. Learning how to knap would be a transcendental task, as was extraction and production in a mine or quarry (CASTAÑEDA, 2018, p. 716). That is the reason for the importance of understanding the strategies that were used so that such activities were compatible and simultaneous.

4. THE TECHNICAL SYSTEM OF CASA MONTERO

Within the demographic and social-economical context that has been described, mining exploitation must be organised in such a manner that the flint supply would be eminently practical. Groups could not carry large volumes of material, and this may be the reason for carrying out the lithic reduction almost completely at the mine. With the objective of understanding the standards used for the management of siliceous resources on a technical and social level, the study of a significant assemblage of lithic remains recovered during the excavation has been carried out.

The analysed sample belongs to 62 mining shafts, and is composed of 168,000 lithic items, of which 2867 are cores, and 4565 discarded blades, being the largest collection of lithic elements belonging to the Peninsular Neolithic. The study has allowed the identification of Casa Montero as a large centre of blade production, unique to date. Its double nature, as a large-scale extraction and production centre, gives this site a unique character which hampers its comparison to other contexts from the same period. The main production at the mine was oriented to obtain blades for deferred use, such as sickles (CASTAÑEDA *et al.*, 2015). Blade products have a mean predetermined length of around 5 cm (Fig. 3). This means that, even though the size of the flint nodules of Casa Montero allows the extraction of longer blades, this length was previously and intentionally established. The predetermined length was obtained by using three strategies: the selection of large flakes used as blanks for cores, the orientation of this initial blank to locate the blade front on an axis of 5 cm, and the extraction of a tablet from the platform of the core to shorten it, if necessary, before starting the production (CASTAÑEDA *et al.*, 2015, p. 482-483).

This determination for obtaining a product with a specific dimension indicates that the products must comply to certain specifications regarding the moment of hafting or use, with the objective of facilitating a fast and simple replacement. Thus, it is a highly anticipated production that leaves very few traces or remains in other archaeological contexts such as habitats. The evidence that Casa Montero has provided are two sickle blades with diagonal hafting, scarcely documented in the Iberian Peninsula (IBAÑEZ *et al.*, 2008, p. 190).

Nonetheless, though the main objective at Casa Montero was the production of blades, a complex network of up to seven lithic operative sequences with different objectives was implemented there. All these sequences were harmonically organised to allow the correct functioning of each of them, working as if they were a set of gears. These operative sequences correspond to percussion elements (CAPOTE, 2011); the mining extraction; the production of large flakes; the production of tools from recycled blanks; the production of flakes for making tools; blade production (CASTAÑEDA, 2014, p. 313-314); and apprenticeship. Even though all these sequences are interrelated, this paper focuses on the relation between the last two. For this, it is important to consider apprenticeship as an operative sequence in itself, with its distinctive tasks, its specific phases, its own residues, its own execution times and, as we have seen, its appropriate places.

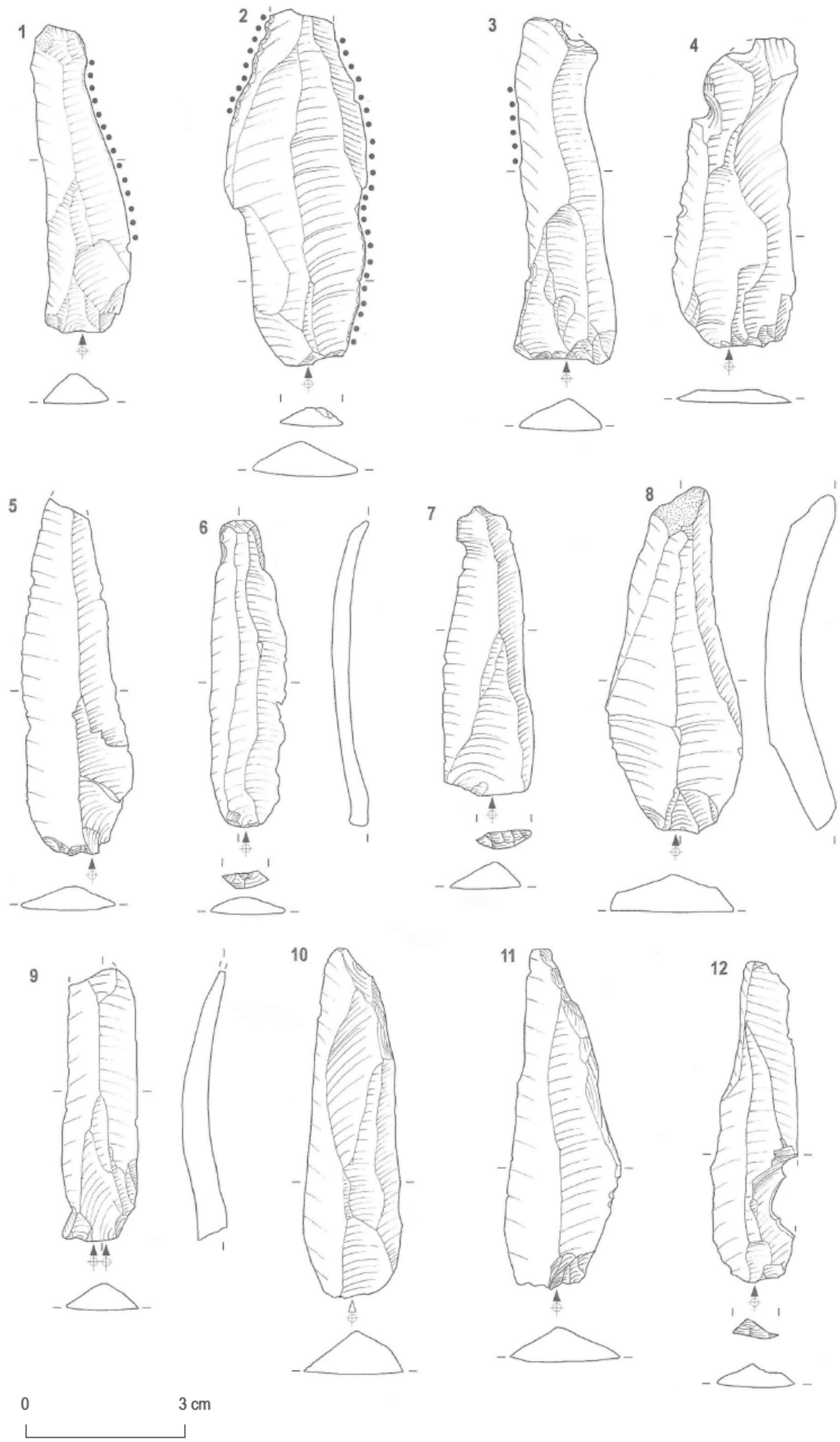

Fig. 3 – Discarded blade products. Drawings: Paco Fernández © Casa Montero project (DÍAZ-DEL-RÍO *et al.*, 2012, p. 467, fig. 10).

5. Apprenticeship at Casa Montero

As has been previously stated, an individual who had not visited the mine could not learn to make a sickle. The individual´s only contact with the final product would be through observation and participation in the harvest. Let the predetermination of the length of the blades products be an example to assess the complexity of the technical actions that would only take place in Casa Montero, and would seem alien to those who had not participated in the actions that happened at this site. As a blade production centre for deferred use, Casa Montero would hold almost the totality of all the know-how on the production of lithic elements. In consequence, this place site would act both as a production centre and disseminator of the technical knowledge regarding flint in all the community.

The apprenticeship that was carried out at the mine left evidences in the object of that apprenticeship: lithic products. Three levels of dexterity have been detected in Casa Montero blade production: expert, advanced apprentice, and novice (Castañeda, 2018, p. 721-729). The criteria used to identify these levels are based on the presence of two types of mistakes: in selection and in execution. The first type expresses the lack of experience regarding the selection of adequate blanks in size, quality and shape or percussion tools. On the other hand, the mistakes regarding execution indicate the inexperience in the gestures or the abstraction of the final product. Among the last group we can find knapping accidents; the excessive or insufficient convexity of the knapping surfaces; the inadequate location of the removals and parts of the core; and evidences of insistent percussion on edges or inadequate places of the core.

The analysis of the characteristics of the cores, once classified by skill levels, reveals that the most important aspect shared by both advanced apprentices and novices is the premature abandonment of the reduction process, mainly due to errors in selection and execution, being its correction impossible (Castañeda, 2018, p. 724-725).

The presences of many cores (18.30 %) abandoned by experts and advanced apprentices that could have continued been worked on, together with some very elaborate elements made on low quality raw material blanks, systematically discarded at the site, support the hypothesis regarding a guided learning by means of demonstrations that are later imitated by the apprentices (Castañeda, 2018, p. 725-726).

6. Blade making and transmitting knowledge

The way in which blade production and apprenticeship sequences relate each other at Casa Montero depends, at least, of two factors: the characteristics of the raw material and the learning in context.

Regarding the raw material, the flint from Casa Montero presents some distinctive characteristics (Bustillo *et al.*, 2009, p. 177, 193) if compared to the other abundant siliceous outcrops in the Madrid basin. Silicification was produced on magnesium smectites leading to the formation of opals and opaline flint. The different siliceous episodes were then affected by an aging process that lead to the inner re-crystallisation of the opaline nodules, transforming them into flint with high quartz contents (Bustillo *et al.*, 2009, p. 193-194). As a consequence of this process, up to three siliceous varieties with different levels of silicification and different knapping responses can occur within a Casa Montero nodule.

The groups of miners developed a selective strategy in which the opal and opaline flint outer parts of the nodules were systematically discarded at the beginning of the reduction process during the initial configuration, or by selecting initial blanks that did not contain these less silicified varieties (Castañeda *et al.*, 2015, p. 481). This strategy added to the heterogeneity of continental flint, led to the abandonment and discard of a high percentage of flint extracted from the shafts (99.81 % of the total mined weight; Castañeda, 2014, p. 321). This result indicates that the amount of raw material available for apprenticeship was limited, since this activity would require large amounts of stone. Therefore, to be able to carry out both activities simultaneously avoiding competition over flint, it is possible to think that the discarded material from blade production would be used for the operative sequence of apprenticeship.

To analyse the relation between the operative sequence of apprenticeship and it source of raw material, we have carried out a multiple correspondence analysis of 822 cores (Fig. 4). The variables used are the three identified skill levels (expert, advanced apprentice, novice); the predominant siliceous variety present in the blanks (opaline, recrystallised); the quality of the blank (heterogeneous, homogeneous, in relation with the presence/absence of geodes, veins or fissures), the origin of the blank (original, such as flakes and nodules, or recycled/reconfigured); and their size (extremely small for blade reduction or of the proper size). The first two obtained factors explain 40.81 % of the variance of the sample (F1: 21.35 %; F2: 19.46 %).

The results relate the three levels of dexterity with different qualities of the blanks that were used. Novices appear next to the most heterogeneous material. During this phase of apprenticeship, initiation to knap would be focused on acquiring the gestural practice. This phase consumes large amount of stone since inexpert strikes produce internal fissures on the core, and failed removals produce the destruction of appropriate surfaces and edges. The abandonment of these cores happens at an early stage (CASTAÑEDA, 2018). Therefore, novices would use the lowest quality raw material that would be discarded even during the phase of extraction from the shaft. Nevertheless, it is very hard to improve and continue learning more complex processes using this type of material.

Advanced apprentices are mainly related to opaline varieties of flint blanks, discarded in the initial configuration of blade cores. This variety of flint is more fragile than recrystallised flint, since its quartz content is lower (BUSTILLO *et al.*, 2009, p. 185). Therefore, it presents good attributes for learning how to manage the volume of the core and how to shape it, but not enough for the use of the final products. Furthermore, the use of this

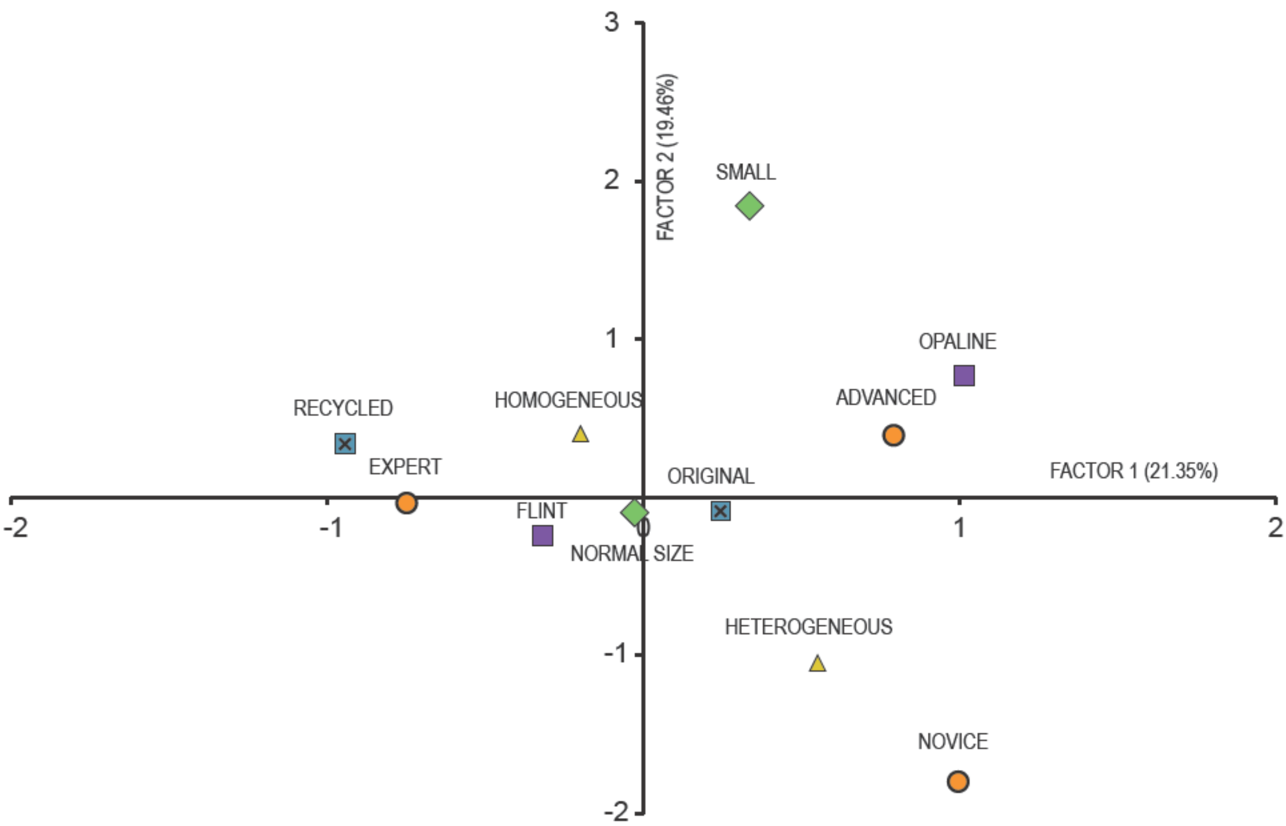

Fig. 4 – Multiple Correspondence Analyses between raw material selection and skill: factors 1 and 2.

material does not affect the productivity of blade production at the mine. In the same way, this skill level occasionally uses nodules that, due to their small size, cannot be complex shaped, but may have a better quality (Fig. 5).

Lastly, the cores made by experts are related to the best quality homogeneous blanks in recrystallised flint, which are also reconfigured for its maximum exploitation.

Taking into account these results, blade production and apprenticeship were possible and compatible, in the case of Casa Montero, thanks to the implement of an extraordinary strategy of raw material selection and management strategy of the raw material that consists in three core ideas (Fig. 6). Firstly, the selection of useless nodules, both the heterogeneous and extremely small ones; secondly, the recycling of opaline discards from blade production; and thirdly, the reconfiguration of cores that were productive and still preserve high quality flint. The first two principles contribute to avoid the competition with blade production over raw material. Nevertheless, the last one would be related with motivation (GRIMM, 2000, p. 64; STOUT, 2002, p. 694), since products made with good quality flint could be useful, which would allow the apprentice to advance in their learning.

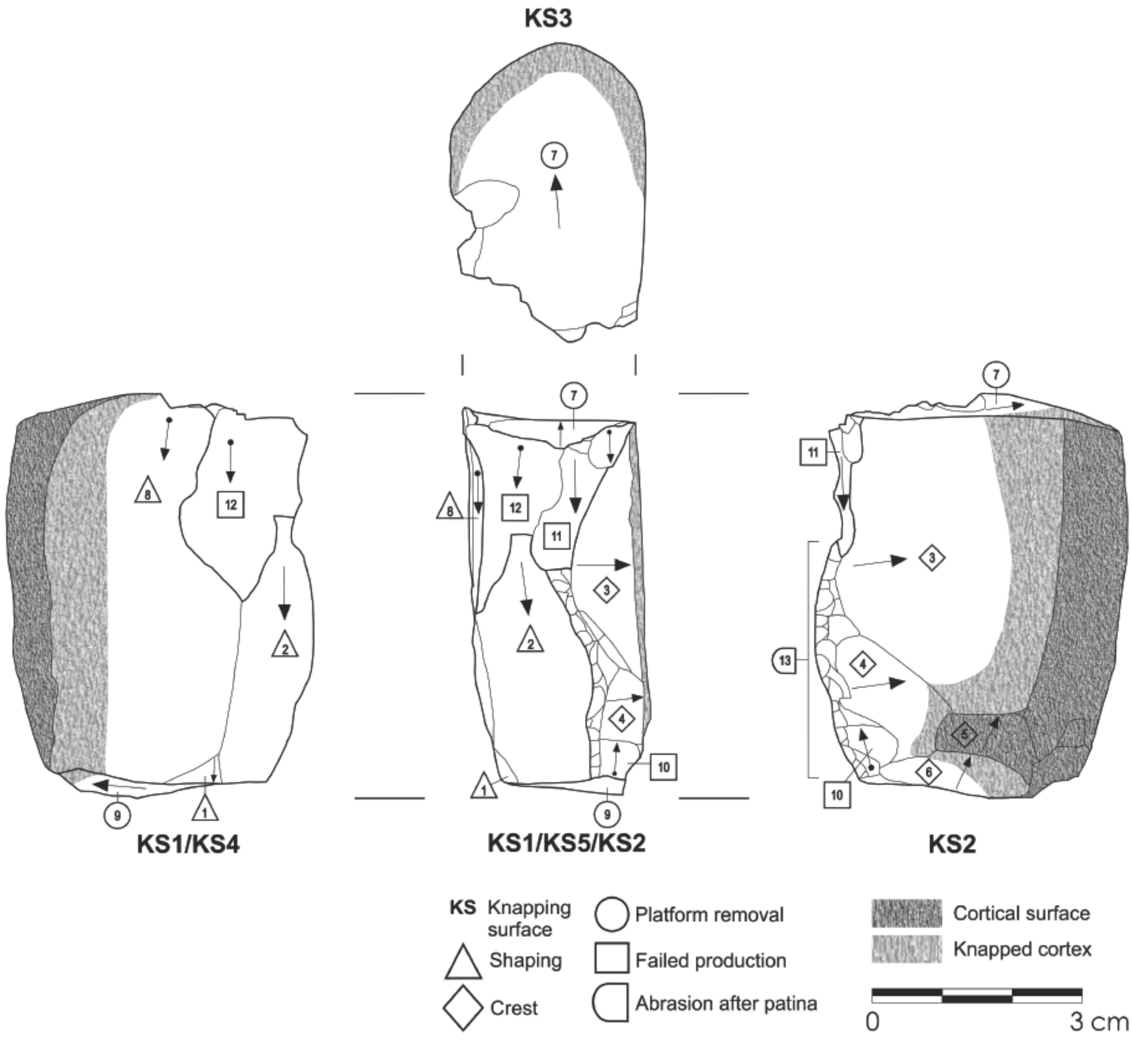

Fig. 5 – Example of a core elaborated by a beginner knapper. Number: 1600_389_3.
Drawings: Paco Fernández © Casa Montero project.

According to learning in context theory, apprenticeship takes place whenever it is useful for the whole group, beyond the transmission of knowledge itself (BARKAI & GOPHER, 2013, p. 129; LAVE & WENGER, 1991, p. 110). The objects made by an apprentice cannot only stay at a level

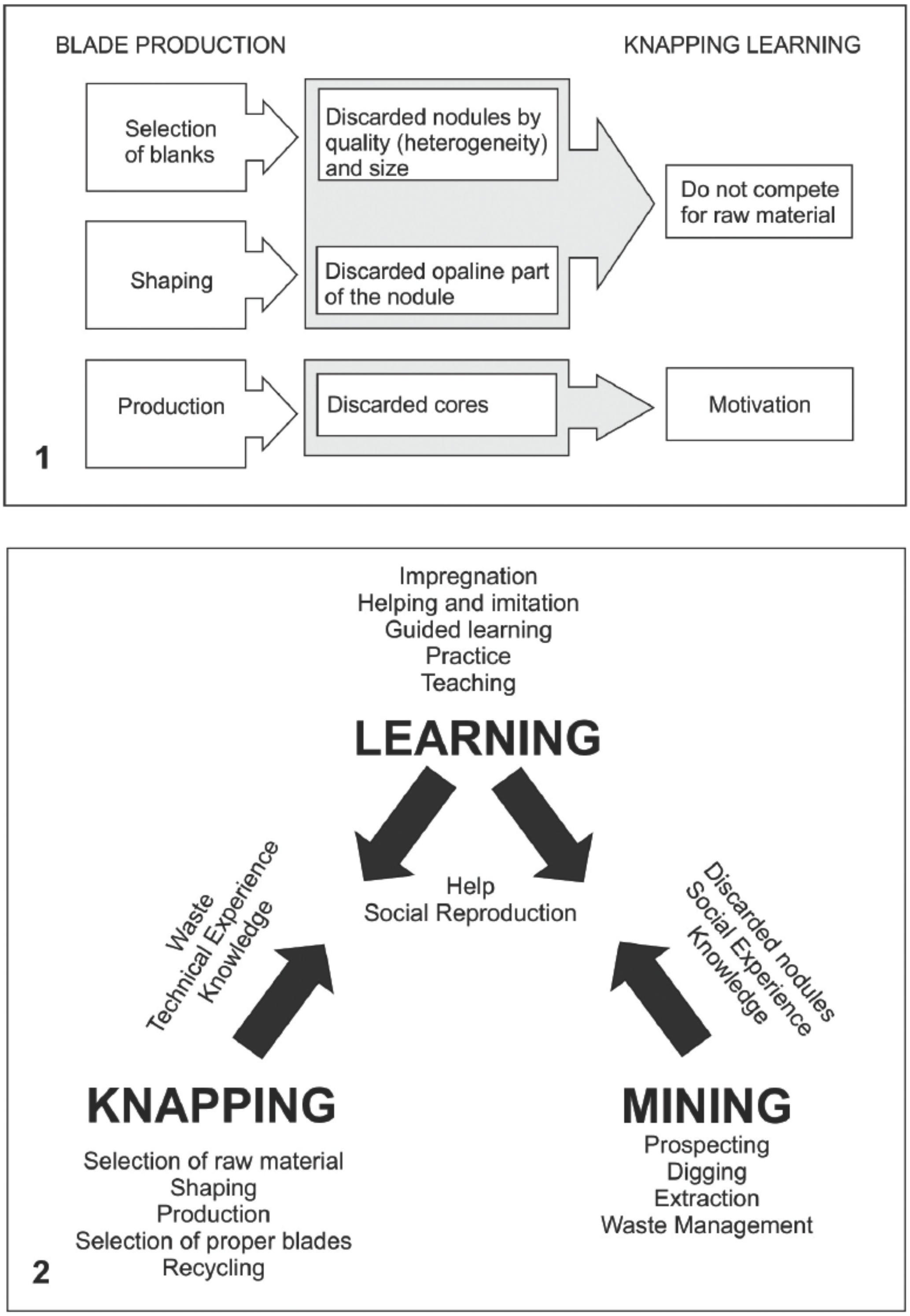

Fig. 6 – 1. Knapping learning raw material selection sources from blade production waste. 2. Relationship between mining, knapping and learning.

of pedagogical practice; rather they must be able to be used. The final use of an object works as a reward for the apprentices and reinforces their motivation for further learning. This would be a benefit that would allow social reproduction.

Therefore, the youngest members of the community would progressively be introduced into this complex technical system, participating in different tasks and phases of the complete productive process, from extraction to the recycling and management of waste. Mining offered them discarded raw material, social experiences and knowledge; blade production would give them large amounts of waste, technical experience and skill; while the participation of new generations would provide the community with a workforce and would allow social reproduction.

7. Conclusions

The analysis of the transmission of knowledge in Holocene chronologies in which the evolution of human cognition is not on the light-spot, allows us to study the phenomenon as an independent operative sequence around which human groups develop strategies *ad hoc* for the generational transmission of technological knowledge.

Mines, together with quarries and different knappable rock outcrops, can be favourable places for the identification of evidence regarding knapping apprenticeship (Audouze & Cattin, 2011), which in many occasions is given for granted and is not specifically studied.

Recent studies of the lithic assemblage from Casa Montero have provided knapping learning evidences (Castañeda, 2018). This apprenticeship, itself, can and must be considered as an operative sequence, in which different phases in the acquisition of knowledge that can be distinguished and that produce their own remains.

The operative sequence of learning at Casa Montero was not isolated. It conformed, together with another six interrelated operative sequences, the complex technical system that was performed at the mine. This paper has evaluated the interaction between the sequences of apprenticeship and blade production that was simultaneously carried out at the same place, using the same lithic resources.

The analysis has determined that its coexistence was possible thanks to the existence of a strategy that solved the two main problems: the restrictions of raw material and the necessity of motivation. In the first case, the use of discarded material from blade production as a raw material source for learning prevented the competition of both sequences over raw material. In the case of the second problem, the inclusion of younger individuals in production tasks as they learned, together with their progressive access to higher quality flint allowed for a better apprenticeship and their inclusion as members of the group.

New socio-economic context triggered by the first Neolithic traits and technologies created the conditions for the development of new political scenarios, a result of the renegotiation of previous collective social arrangements. At this point in time, Casa Montero acted as the arena for the transmission of technical knowledge, collective action and political negotiation among small autonomous social groups.

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The flint mine site Wierzbica 'Zele' (Poland) and Bronze Age workshop materials after forty years of new research (1979-2018)

Jacek LECH & Dagmara H. WERRA

Abstract

Between 1980-1988, the 'Zele' flint mine in Wierzbica, Radom district (Poland), was among the most extensively excavated prehistoric flint mine sites in Europe. 'Zele' is distinguished by the presence on the surface of small limestone slabs and rubble mixed with flints and ploughed soil. On the basis of research carried out so far, it is certain that the mine was operated for several hundred years in the Bronze Age. The purpose of the present article is to describe the excavations and the main research results. The paper presents new characteristics of the 'Zele' flint, a variety of 'chocolate' flint from Central Poland, and the morphological and weight structures of flint inventories from the mining site.

Keywords: Bronze Age, flint mine, chipped flints, 'paracore', 'chocolate' flint, Wierzbica 'Zele', archaeology of Poland.

Résumé

De 1980 et 1988, la minière à silex de « Zele » à Wierzbica dans le district de Radom (Pologne) fut l'une des mines de silex préhistoriques la mieux fouillée d'Europe. Le site de « Zele » se caractérise par la présence en surface des plaquettes et débris de calcaire mélangés à du silex et du sol cultivé. Sur base des recherches réalisées jusqu'à présent, il est certain que la minière fut en activité durant plusieurs siècles, au cours de l'Âge du Bronze. Cette contribution a pour objet de décrire les fouilles et les principaux résultats des recherches. L'article présente également les nouvelles caractérisations du silex de type « Zele », une variété de silex « chocolat » du centre de la Pologne ainsi que la structure morphologique et quantitative de l'assemblage lithique du site minier.

Mots-clés *: âge du Bronze, minière à silex, silex taillés, « paranucléus », silex « chocolat », Wierzbica « Zele », archéologie de Pologne.*

1. INTRODUCTION

Wierzbica is a large village with medieval roots, the seat of the municipality, twenty kilometres south of Radom, a medium sized city in Central Poland. The village and the Wierzbica 'Zele' flint mine site lie in the area of the Iłża Foreland, near the border with the Radom Plain (Fig. 1).

Fig. 1 – Wierzbica, Radom District (Poland). Autumn 1979. A general view on the area of the prehistoric flint mine site 'Zele' and its surroundings. Photo by J. Lech.

The site (51°14'47''N, 21°03'10''E) has been the subject of several articles and several unpublished conference papers (e.g. MŁYNARCZYK, 1983; LECH, 1984, 1995, 1997a, 1997b; LECH *et al.*, 2011, LECH *et al.*, 2015).

2. THE 'ZELE' FLINT

The site is situated in a belt of chocolate flint deposits which occur in the Upper Jurassic limestone and karstic clays. Under topsoil, in the natural stratification of the site, there is a layer of Pleistocene sands mixed with boulder clay. Underneath, there is a layer of clay containing flints of different shapes and sizes and, still deeper, a layer of weathered Upper Jurassic (Late Oxfordian) oolitic and clayey limestones, also with flints (LECH, 1984, p. 186, 1995, p. 467; PŘICHYSTAL, 2013, p. 108). In some places, small flattened flint nodules and tabular flint plates occur just below the surface, but the large nodules of flint are found at deeper and at the deepest exploitation levels.

The 'Zele' flint exploited only at Wierzbica is a variant of 'chocolate coloured flint' from Central Poland. It has been given the general name of 'Zele' type chocolate flint, whose weak gloss and the appearance, at times, of sharp borders between the black and brown colours in the silica distinguishes it from other types of chocolate flint (Fig. 2). The raw material appears in various forms from small, flat nodules to large plate shaped and bulbous nodules, very large bulbous nodules, reaching even 100 cm in diameter. The latter occurs in prehistoric features very rarely, because their deposits are situated deeper and usually were not exploited (SCHILD, 1971, p. 8-11, 34-35, 1976, p. 147-150, 1987, p. 137-139, 148; LECH *et al.*, 2011, p. 109-111).

Fig. 2 – Wierzbica, Radom district (Poland). The prehistoric flint mine site 'Zele'. Nodules of 'chocolate' flint of the 'Zele' type (medium size), originating from excavations in Cutting I/80. Photo by J. Lech.

The 'Zele' flint is characterised by low porosity (Fig. 3:1). The pores are usually small and are often formed by the dissolving of calcite crystals present in the nodule. Negatives of rhombohedral calcium carbonate crystals (Fig. 3:2) and traces of completely silicified microfossils have often been found. Their presence is usually visible at the edges of nodules that have undergone a patination process. Removal of even a small amount of silica reveals the primary sedimentation structures.

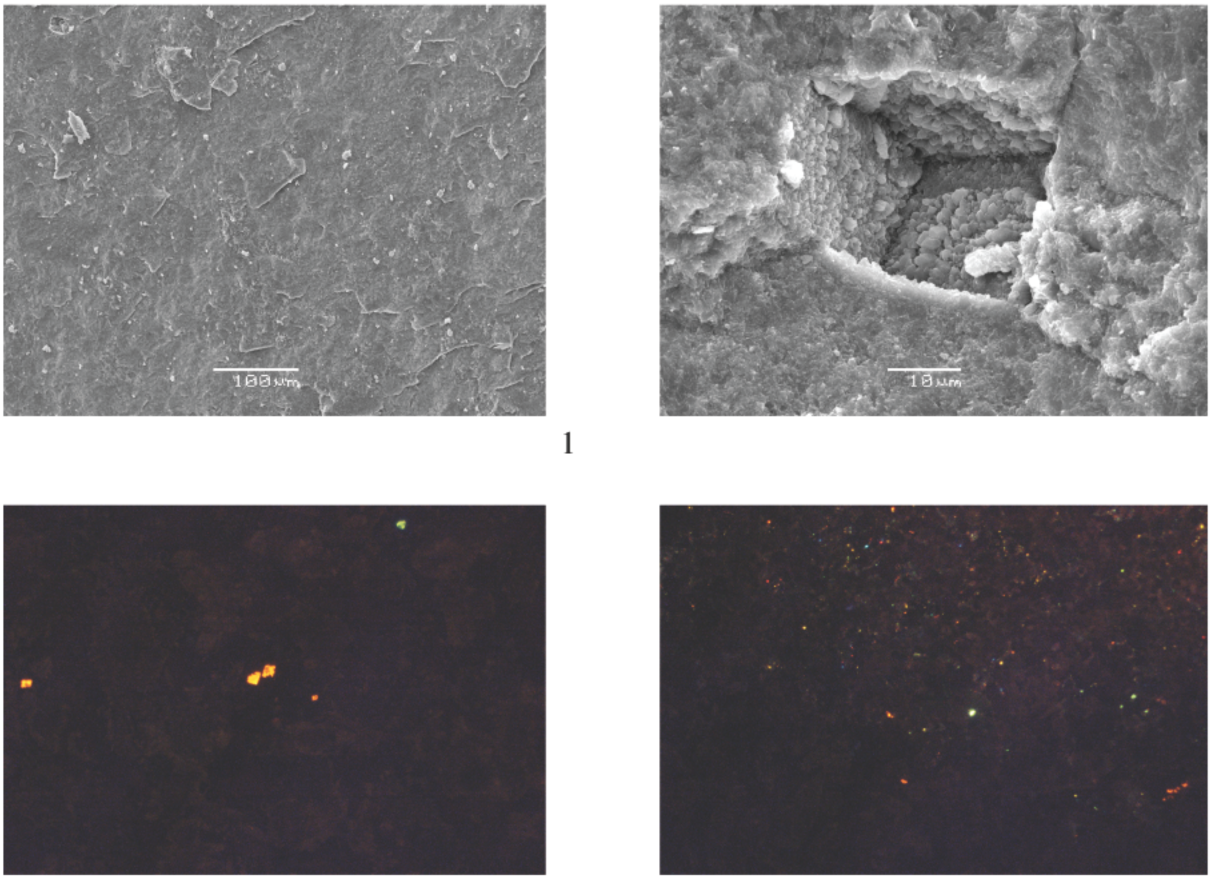
When analysing the 'Zele' flint, the cathodoluminescence of accessory minerals was observed, most often orange luminescence of calcite (Fig. 3:3). The character of the luminescence does not depend on the form in which the calcium carbonate occurs. Both the syngenesis calcite and small, relic extrusions of calcite luminesce in the same way. In one case calcite was observed to glow orange, forming irregular shaped aggregates occurring in 'chocolate' flint from the old quarry of the 'Przyjaźń' cement works in Wierzbica. A bright yellow luminescence in cathodoluminescence radiation is characteristic of small concentrations of baryte occurring in flint from the Wierzbica 'Zele' site and from the Wierzbica quarry (Fig. 3:4). This type of luminescence is connected with the presence of apatite. Apatite usually has a very weak grey-brown glow, a characteristic feature when it builds phosphate organic remains present in flint. The second type of luminescence of apatite is a blue colour, observed only in the case of small autogenous apatite hexagonal prisms. This type of apatite was found in flint from the Wierzbica quarry and from the Wierzbica 'Zele' site (see Fig. 3:5; WERRA & SIUDA, 2015a and b; the presented results were obtained during work on the project financed with funds provided by the National Science Centre – PRELUDIUM 2 DEC-2011/03/N/HS3/03973).

3. THE FIRST RESEARCH AND EXCAVATIONS OF THE WIERZBICA 'ZELE' FLINT MINE

The site was discovered before the Second World War by the well-known Polish prehistorian Stefan Krukowski (SCHILD, 1997-1998, p. 347-348). S. Krukowski (1890-1982), a pre-eminent researcher of the Palaeolithic and chipped industries, was also a pioneer in studies of prehistoric flint mining in Poland (LECH & PIOTROWSKA, 2009).

In the beginning of 1972 the government of the Polish Peoples Republic began to build a new cement plant in Wierzbica. As part of the project, a concrete road adapted to the traffic of heavy vehicles was built across 'Zele', leading to a quarry of Jurassic limestone, being prepared for the new plant. The road on its south side, by about one metre cut into a slight elevation of the terrain. The rescue excavations were necessary.

In the summer of 1979 it was decided to divide the research project into two stages. Stage I – the reconnaissance, 1979-1980, was to decide about the scope of the work and the methods used in the next stage. Stage II was to begin with excavations in 1981. The aim was to reconnoitre the mine – to determine the type of



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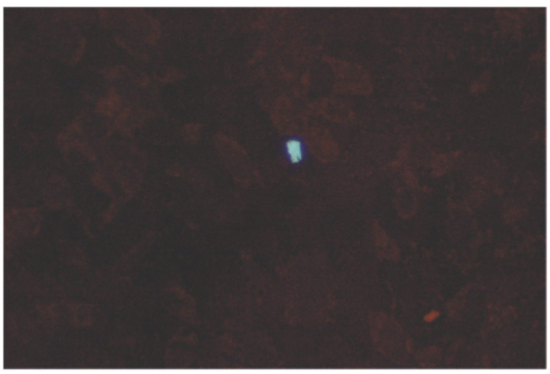

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Fig. 3 – Wierzbica 'Zele', Radom district (Poland).
Scanning electron microscope photos:
1. Surface of 'Zele' type chocolate flint;
2. Negatives of rhombohedral calcium carbonate crystals. Luminescence in cathodoluminescence radiation; 3. Orange colour luminescence of calcite;
4. Yellow colour luminescence of small concentrations of baryte;
5. Blue colour luminescence of small autogenous apatite hexagonal prisms.
Photos 1 and 2 by R. Siuda.
Photos 3-5 by M. Sikorska-Jaworowska.

exploitation units, their extent, the boundaries of the mining field, the period when the deposit was exploited and directions of the flint work. These were rescue excavations as the area was still intended for industrial investment. The excavations were to make such use possible.

From October 10-17, 1979 a systematic survey of the 'Zele' surface was carried out by Hanna Młynarczyk with the participation of three other archaeologists (Jacek Lech, Piotr Miglus and Franciszek M. Stępniowski). In one week, the team drew a map showing the occurrence of basic categories of archaeological materials (flints and limestone pieces) on the surface of the site on a scale of 1:500. The area of distribution of the materials, resembling in shape a human kidney, was determined. In 1979 its longer axis stretched 400 m and shorter 300 m (MŁYNARCZYK, 1983, p. 88-91; LECH, 1983, p. 64-67; LECH, 1984, fig. 1, 2, p. 188-190). On the surface of the ploughed fields, there were numerous flint specimens – natural (mostly) and worked. No fragments of pottery, either from prehistoric or medieval times were found. It was believed that the Wierzbica 'Zele' flint mine was used intermittently from the Late Palaeolithic to the Early Bronze Age (LECH, 1983, p. 67; MŁYNARCZYK, 1983, p. 105).

In 1980 Tomasz Herbich, conducted the first electrical resistivity imaging on part of the site where the first cutting was being planned (HERBICH, 1993). The results were used to locate Cutting I/80 (Fig. 4). The first excavations in 1980 were aimed at determining the natural geological stratigraphy of the site, determining the type and size of features used to exploit the raw material and documenting the features that were impaired by the concrete road. They were carried out by H. Młynarczyk, with the participation of J. Lech, in the summer of 1980. The cutting, 10 x 5 m, included two zones of ground resistivity, distinguished as a result of the electrical resistivity survey. The archaeologists were looking for the key to applying this method in the course of further excavations of the site. At a depth of 30 cm, the area of further exploration was limited to 3 m x 10 m. The obtained profile was cut through the zones with the greatest diversity of substrate resistance. Cutting I/80 was dug near the slope of the road passing through the site, so as to be sure of coming across the shafts. Five open shafts of up to several metres width at the surface were found. Their depth ranged from 4.5 m to 5.5 m. Trench II/80, 240 m^2 in area, was located at the side of the road between the edge of the concrete road surface and the slope. The slope of the road and the roadside were cleared and recorded (Fig. 5).

Fig. 4 – Wierzbica, Radom district (Poland). The prehistoric flint mine site 'Zele'. View of Cutting I/1980. The excavations were supervised by Hanna Młynarczyk. Photo by J. Lech.

In the years 1981-1988 stage II was completed. H. Młynarczyk (from 1982 H. Lech) led the excavations in 1982. In 1983 the 'Zele' excavations were conducted by J. Lech and, in the years 1985-1988 further excavations were conducted by H. Lech (LECH, 1984, 1995, 1997a, 1997b; see LECH & PERLIKOWSKA-PUSZKARSKA, 2009, p. 269-270).

During the first two excavation seasons (1980 and 1981), 23 shafts and 3 other features, probably also shafts, were located. Fifteen shafts were discovered in the archaeological cuttings. Fragmentary sections were determined for 12 of them in the profiles of the cuttings and in the balk. Full vertical cross-sections were obtained for shafts 1, 6 and 7 (Fig. 4 and Fig. 5). The results of the first three excavation seasons at the 'Zele' site were summed up in an article by H. Młynarczyk (1983). The purpose of further investigations of the

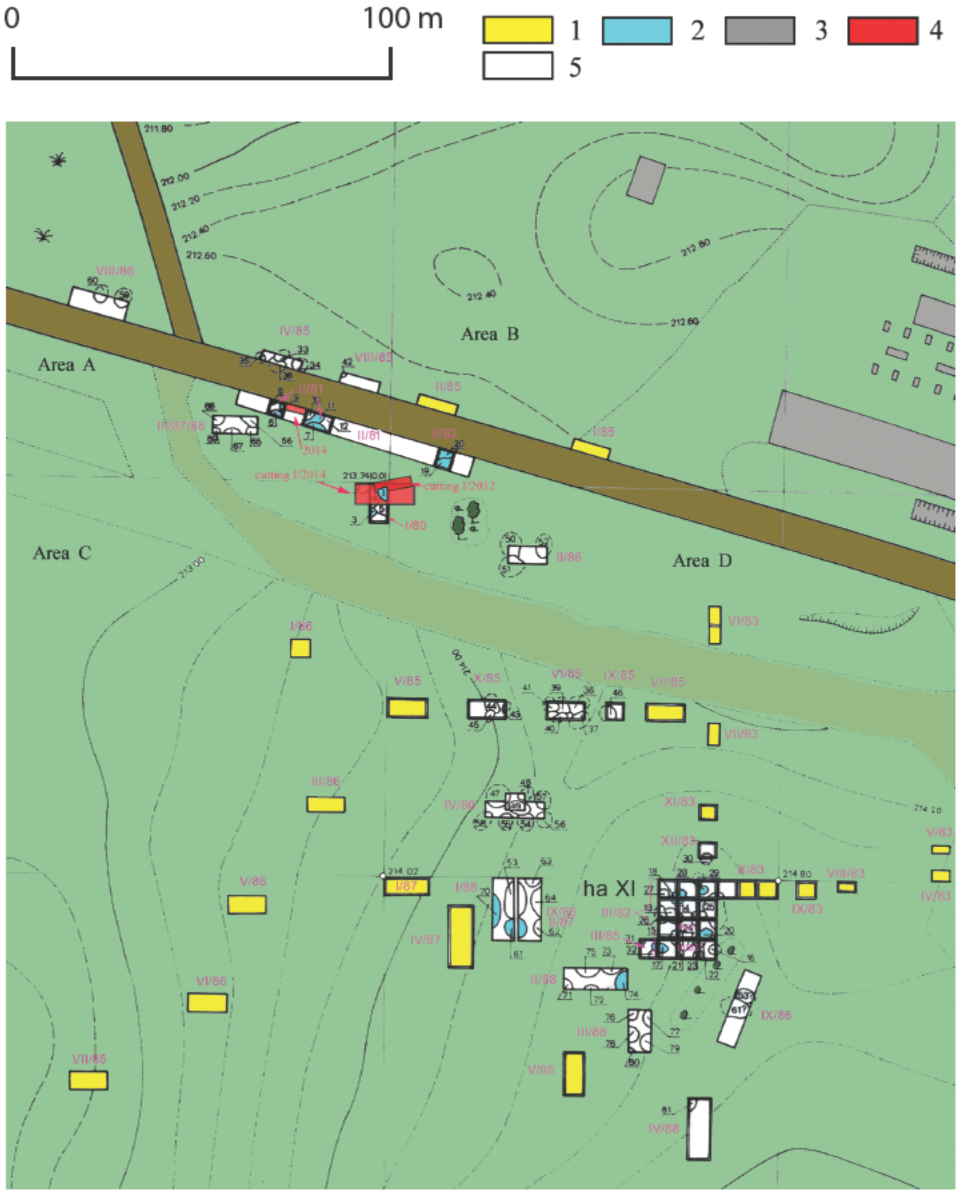


Fig. 5 – Wierzbica, Radom district (Poland). The prehistoric flint mine site 'Zele'.
Map of the distribution of cuttings and shafts 1980-2014:
1. Cuttings without shafts; 2. Shafts mentioned in the text;
3. Remains of unfinished buildings and structures of a new limestone quarry;
4. Cuttings from 2012 and 2014; 5. Cutting with shafts.
Measurement and drawing by J. Fellmann; completed by H. Lech and D.H. Werra.

'Zele' mining field was to define its boundaries, to distinguish between the different mining features and to determine their chronology (Fig. 6).

Today we know that siliceous rocks were exploited and used since the Early Bronze Age to the end of the Bronze Age and beginning of the Iron Age (LECH *et al.*, 2011; LECH & WERRA, 2018, p. 580-581; Fig. 6), but in 1983 it became of great importance to obtain further charcoal samples to verify the first results. Therefore, the purpose of the 1983 excavations carried out by J. Lech was to investigate Shaft 28.

The excavation of Shaft 28 covered an area of 16 m^2 (Fig. 5). The shaft went down for

No.	*Site*	*Laboratory number*	*Origin of the sample (feature)*	*b.c.*	*+/-*	*Literature*
1	Ożarów, site "Za Garncarzami", Poland	Gd-2114	Shaft I/3	1570	80	Budziszewski, 1997, p. 51
2		Gd-2115	Shaft I/4	1480	80	
3		Gd-2108	Shaft I/3	1420	80	
4	Polany, site II, Poland	Bln-4175	Shaft 1/1988	1800	80	Herbich & Lech, 1995, p. 504
5		Bln-4176	Shaft 1/1988	1740	80	
6		BM-1235	Shaft 1/1972	1541	81	Lech & Leligdowicz 2003, p. 151
7		Bln-4174	Shaft 3/1988	1540	80	Herbich & Lech, 1995, p. 502
8		Bln-4173	Shaft 3/1988	1450	70	
9	Wierzbica, site "Zele", Poland	MKL-1107	Shaft 70	1830	60	Unpublished
10		GrN-11852	Shaft 17	1730	70	Lech, 1984, p. 194
11		GrN-11854	Shaft 17	1720	60	
12		Poz-44122	Shaft 61	1680	35	Unpublished
13		GrN-11853	Shaft 17	1620	90	Lech, 1984, p. 194
14		MKL-1106	Shaft 74	1500	50	Unpublished
15		BM-2383	Shaft 20	1200	80	Lech, 1997a, p. 103
16		BM-2386	Shaft 28	940	110	
17		BM-2386A	Shaft 28	850	100	
18		BM-2385A	Shaft 28	830	80	
19		OxA-5101	Shaft 19	830	45	Hedges, *et al.*, 1996, p. 408
20		BM-2385	Shaft 28	800	70	Lech, 1997a, p. 103
21		GrN-11856	Shaft 18	720	60	Lech, 1984, p. 194
22	Krumlovský les, Moravia, Czech Republic	GrA-23556	Pit; trench I-1-1	1680	50	Oliva, 2010, p. 266; 2011, p.100
23		GrA-23559	Shaft; trench III-1-1	1540	50	
24		GrA-22835	Spoil heap; trench IV-2-1	1390	45	
25		GrA-29162	Shaft; trench V-5-1	1560	50	
26		GrA-30352	Shaft; trench VII-4-1	1360	40	
27		GrA-34262	Shaft; trench II-10-3	1540	35	
28		GrA-38107	Workshop; trench I-13-1	1690	30	
29		GrA-38112	Shaft; trench II-20-1	1415	30	
30		GrA-38113	Shaft; trench II-22-1	1305	30	
31		OxA-22463	Shaft; trench I-13-1	1682	30	
32		OxA-22464	Shaft; trench I-13-1	1627	28	
33		GrA-28034	Shaft; trench V-2-2	1220	35	
34		GrN-28875	Shaft; trench II-9-1	890	50	
35		GrA-38081	Shaft; trench I-11-2	805	25	
36		GrA-38108	Shaft; trench II-2-2	810	30	
37		GrN-28873	Shaft; trench II-11-1	515	55	
38	Krasnaselsky (former name: Krasnoye Selo), Belarus	LE-915	no data	1560	110	Gurina, 1976, p. 127
39		LE-680	Shaft 12	1420	50	Dolukhanov, *et al.*, 1970, p. 132
40		LE-636	Shaft 2, 3 i 12	1240	60	
41	Polany Kolonie, site II, Poland	Gd-133	Shaft 7	1550	90	Schild, 1995a, p. 484
42	Karpaucy (former name: Karpovcy), Belarus	LE-914	no data	1540	70	Gurina, 1976, p. 127
43		LE-913	no data	1400	80	
44	Bečov, Czech Republic	Bln-552	Shaft 5	1530	80	Kohl & Quitta, 1970, p. 403
45		Bln-553	Shaft 1	1455	80	
46	Tomaszów, Poland	Gd-5196	Neighborhood of a shaft in the NE part of the mine	1280	40	Schild, 1995b, p. 462

4.5 m, with 2.5 m cutting through weathered limestone rock in which flint nodules occurred at various levels (Fig. 7). Shaft 28 provided a rich sampling of charcoal contemporaneous with the time when it was sunk and from the early stages of its backfilling (Fig. 6). These samples, like the first ones from the 'Zele' shafts, were sent to the Research Laboratory of the British Museum (LECH, 1995, p. 469-479; LECH & LELIGDOWICZ, 2003, p. 293, tab. 1; LECH *et al.*, 2011, p. 111-113, fig. 5). The results showed unequivocally that Shaft 28 was dug in the Late Bronze Age, around 1000 cal BC, at the time of the Lusatian culture from the Central European Urnfield complex (cf. HARDING, 2002, p. 273-274). The dates for the four charcoal samples sent to Groningen arrived in October 1983. Three of them dated with certainty Shaft 17 from Cutting III/82 to the Early Bronze Age – the time of the Mierzanowice culture. The fourth sample, from the same cutting, collected below the waste dump of Shaft 18, again indicated the Late Bronze Age (LECH, 1984, p. 194, table 1). In total, all 15 radiocarbon dates for charcoal samples from 8 shafts located in two distant regions of the mine are from the Bronze Age or Early Iron Age (see LECH & LELIGDOWICZ, 2003, p. 293, tab. 1).

In the years 1985-1988 the boundaries of the mining field were defined in a series of excavations. In total, between 1980 and 1988, 44 archaeological digs were carried out at the site and in its immediate vicinity, and 81 shafts and different exploitation units were located (Fig. 5). Some of the shafts were explored.

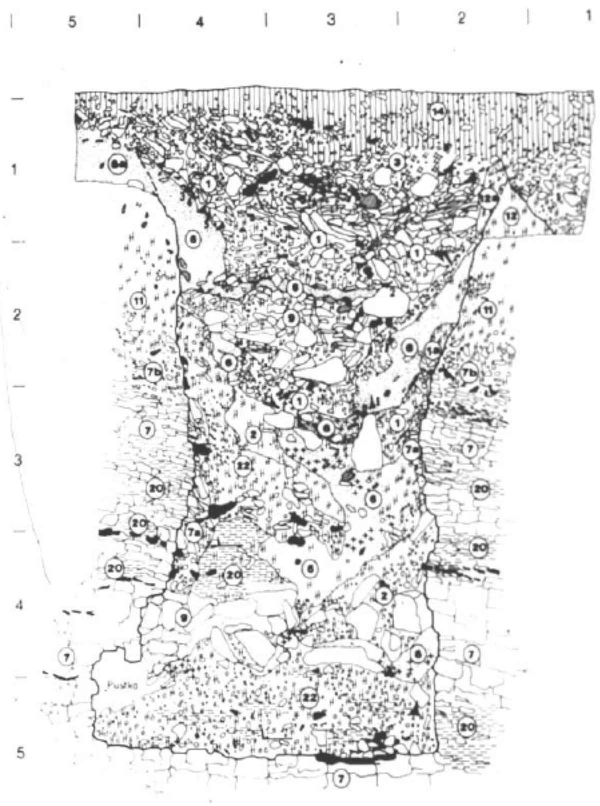


Fig. 7 – Wierzbica, Radom district (Poland). The prehistoric flint mine site 'Zele'. Cutting III/1983. Cross-section of shaft 28. Drawing by M. Ślązak.

4. NEW EXCAVATIONS

Changes in Poland's political system, which entailed privatisation and rationalisation of the industry, led to the closure and liquidation of the cement plant in Wierzbica in 2000. Since 2010 research of the 'Zele' mine has been carried out by the Autonomous Unit for Prehistoric Flint Mining at the Institute of Archaeology and Ethnology Polish Academy of Sciences (IAE PAN).

In 2014, after a hiatus of almost 30 years, the Autonomous Unit from IAE PAN, in cooperation with the Institute of Archaeology of the Cardinal Stefan Wyszyński University in Warsaw (UKSW), returned to the excavations of Shaft 1. The reasons for the resumption of excavation work was that during the studying of flint materials obtained from this feature in 1980, fine fragments of flakes and waste, normally produced during the processing of raw material, were found to be absent. The purpose of the new excavations was to obtain the entire flint material, including the fine and very fine fractions, to recreate the original structure of the inventory from the filling

Fig. 6 – (opposite page) 'Zele' mine in Wierzbica, Radom district, compared to other mines of siliceous rock from the Bronze Age in the east part of Central Europe, in the light of radiocarbon dates (conventional dates b.c.). Dates with standard error greater than ± 110 radiocarbon years have been omitted.

of Shaft 1. An additional reason for returning to the excavation of Shaft 1 was the intention of again uncovering the natural stratigraphic sequence found in 1980 between shafts 1 and 2, in connection with the research project, "Differentiation of Upper Jurassic 'chocolate flint' from Central Poland, from the point of view of identification in archaeological research" headed by Dagmara H. Werra (project financed from funds provided by the National Science Centre – PRELUDIUM 2 DEC-2011/03/N/HS3/03973). The intention was to take from the different levels with chocolate flint nodules samples for petrographic, geochemical and palynological analyses (WERRA & SIUDA, 2015a; WERRA *et al.*, 2015). It was also hoped that charcoal would be found for the radiocarbon dating of Shaft 1, since none was obtained in 1980.

In 2014 excavations of the 'Zele' site were conducted by Dr Dagmara H. Werra in cooperation with Jacek Lech. Cutting I/2014, measuring 7 x 13 m was opened at the site, as well as a small probe trench (S1/2014), 2.13 x 1.37 m intended to determine the border of Cutting II/81 next to the concrete road which ran across the north part of the site. The edges of this trench were to serve as additional points stabilising the measuring grid. Altogether, Cutting I/2014 covered an area of 78 m^2. The exploration was done manually, in layers of 10-20 cm, as it was necessary to remove the layer of material thrown out from the road ditches. A digger was employed only when removing material that had been used in 1980 to fill in Cutting I/80 (Fig. 8).

The excavations yielded large amounts of flint material, most of it natural. Cutting I/2014 can be divided into two zones – the eastern (E), where waste heaps from the shafts were registered and the western (W) part, where the filling of Cuttings I/80 and I/2012 was located. In zone W of Cutting I/2014, where the filling of Cutting I/80 was expected, excavators reached the level at which work had ended in 2012 (level with protective plastic foil). Excavation work then continued in order to determine the borders of Cutting I/80. At the first level in the NW corner, the outline of the shaft's waste heap was noted. A 20 cm layer was removed in order to clear the heap. As exploration proceeded, material was collected separately from each metre and all the material from the excavated sediments was sifted. In part E, under a layer of freshly deposited earth from the beginning of the 21st century and an old layer of ploughed soil, a concentration of limestone rubble was uncovered, together with a few pieces of flint. The arrangement of the excavated

Fig. 8 – Wierzbica, Radom district (Poland).
'Zele' mine. View from E onto cutting from 2014. in the advanced phase of the excavations.
In the foreground Shaft 82 is being drawn, while a digger is uncovering old cutting I/1980,
supervised by Dr Dagmara H. Werra. Photo by J. Lech.

material suggests that the remains of shaft heaps were uncovered. Excavation here was done by hand, clearing the gradually revealed structure of the heap as it was preserved. Altogether, the uncovered waste heaps were spread over an area of 48 m^2. All the excavated layers were sifted. Work then concentrated on further exploration of the filling of Shaft 1 by making an additional cut along an east-west axis running half way through the feature. As work on clearing the newly uncovered waste heaps and their detailed recording was a laborious task, excavations of Shaft 1 were fragmentary. Only two 10 cm levelling layers were removed in the east part of the Shaft 1 filling. Of the 16,971 flint pieces obtained from Cutting I, 3577 were artefacts and 13,394 were natural fragments without any traces of knapping. There was also one stone. The average weight of one specimen was 11.95 g.

5. Bronze Age workshop materials

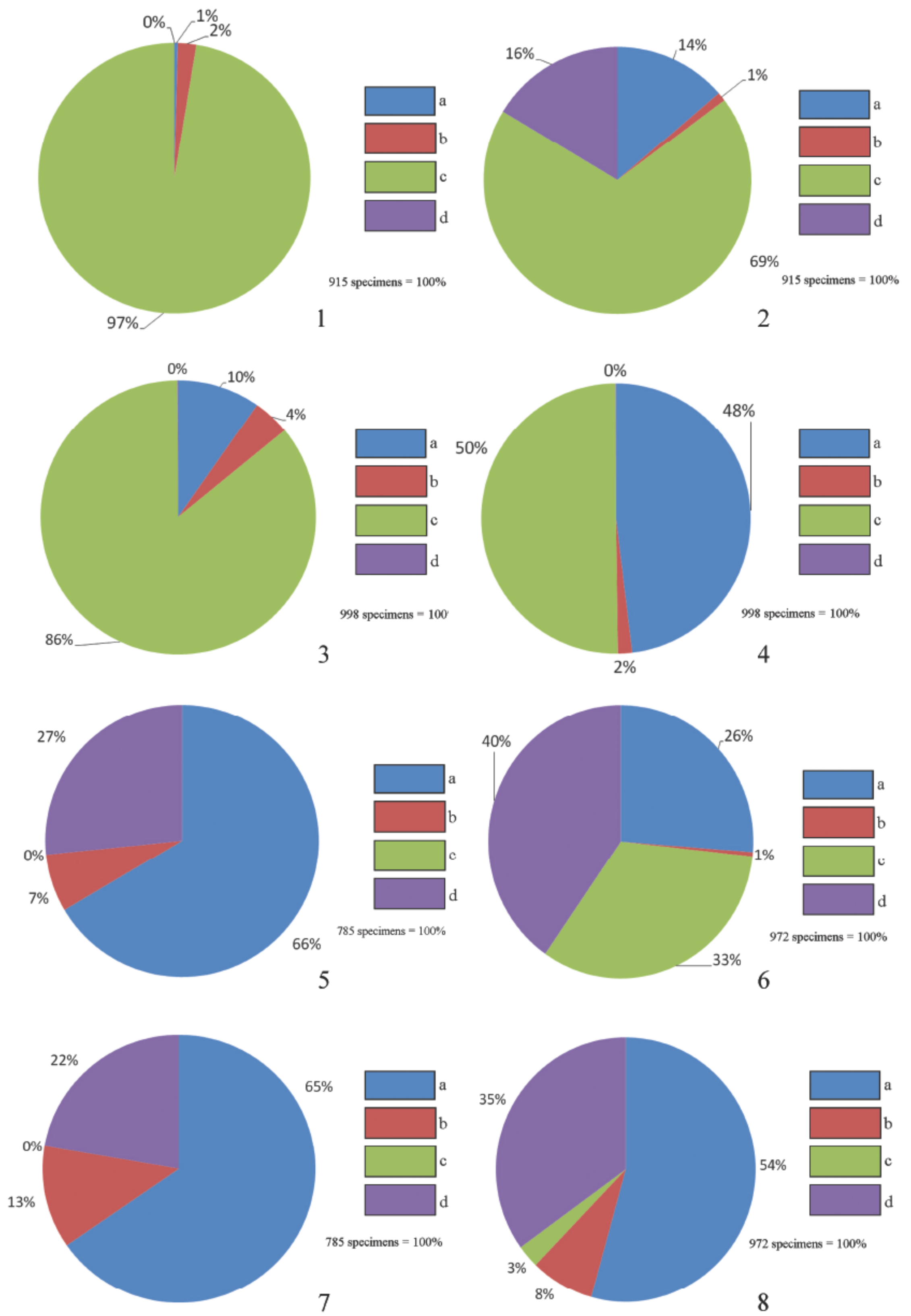
From the flint material found during the excavations in 2014, a sample of 999 pieces was analysed. The morphological analysis was carried out in four morphological groups using the method presented in earlier articles (LECH & LONGWORTH, 2006, p. 415; LECH, 2012, p. 91-109). The results are given in Fig. 9:1. Four specimens, i.e. 0.4 % of the whole inventory, were attributed to the first group (Fig. 9:2). Their total weight was 755.9 g, which comes to 13.6 % of the weight of the whole inventory. The group of blades and blade fragments included 22 specimens (2.2 %) weighing together 59.5 g (1 %). Group III – Flakes and waste was the most numerous and comprised, 972 pieces (97.4 %) weighing together 3820.9 g (68.9 %). The fourth morphological group – tools was represented by just one artefact – a stone hammer (0.1 %) weighing 906.2 g (16.3 %).

At the same time, at the Autonomous Unit for Prehistoric Flint Mining of IAE PAN material from the west part of Shaft 1, excavated in 1980, was also analysed. A sample of 915 flint specimens was also set apart and, after separating it into four morphological groups, was compared in terms of quantity and weight with the structure of the material from 2014 (Fig 9:3-4).

Owing to the small number of specimens in the morphological groups I, II and IV from the excavations in 2014, it was decided that for comparison with the 1980 research, the material from group III, flakes and waste, would be most suitable. In the material from Cutting I/1980, 3123 specimens from these groups were recorded, including 2338 natural fragments and flint nodules in group III. 576 pieces were counted as flakes and 209 as industrial waste (Fig. 9:5). While in Cutting I/2014 were found 3827 specimens and fragments. Among them 580 were flakes, microflakes and chips, and 392 were attributed to the group of industrial waste (Fig. 9:6).

The excavations of Cutting I/1980 yielded primarily complete flakes (522 specimens, weighing 30,625.7 g) and technical flakes. Microflakes and chips were not registered. The average weight of complete flakes was 58.72 g, and of technical flakes 107.31 g (54 specimens, weighing 5794.5 g). The combined average weight of specimens from Group III (without natural pieces) was 59.69 g (Fig. 9:7). Among the material from Cutting I/2014 microflakes and chips predominated – 320 specimens (weighing 107.3 g), followed by complete flakes (255 specimens weighing 2074.5 g) and with only – 5 technical flakes (weighing 302.7 g). The average weight of chips was 0.08 g, microflakes – 0.4 g, complete flakes – 4.24 g, technical flakes 60.54 g. The combined average weight of specimens from Group III (without natural pieces) was 3.93 g (Fig. 9:8).

The complete flakes were also compared in terms of size (Fig. 10:1-2) and weight (Fig. 10:3-4). In material from Cutting I/1980 average flakes predominated, from 50 to 80 mm in diameter (217 specimens), with an average weight of 32.72 g. Next came large flakes (above 80 mm in diameter), weighing on average 142.71 g. There were 149 small flakes, weighing on average 8.66 g. As previously mentioned, during these excavations no microflakes or chips were collected. The situation concerning the size and weight of flakes in the excavations of 2014 was reversed. There were most microflakes with a diameter of 10 to 20 mm – 258 specimens with an average weight of 0.4 g. In second place were small flakes (20-50 mm) of which there were 225 specimens with an average weight of 4 g. 62 chips, weighing on average 0.08 g. were found, followed by 26 medium sized flakes (average weight 32.2 g), and only four large flakes weighing on average



82.75 g. This comparison illustrates the influence of research objectives and methods of collecting flint material on the flint inventories undergoing further investigations.

To sum up:

1. In both compared inventories, divided into four morphological groups, flakes and waste predominate;

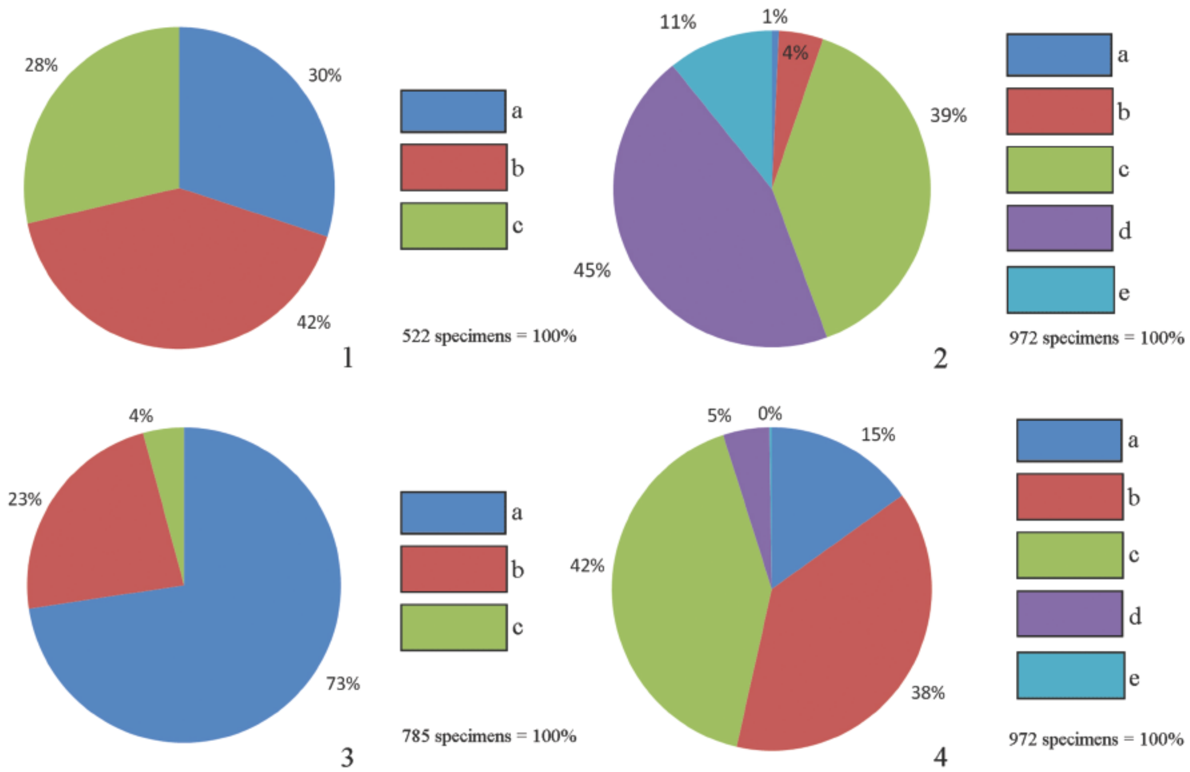


Fig. 10 – Wierzbica 'Zele', Radom district (Poland), structure of flint materials.
a. large flakes > 80 mm; b. medium flakes – 50 to < 80 mm;
c. small flakes 20 to < 50 mm; d. microflakes 10 to < 20 mm; e. chips ⩽ 10 mm;
1. Cutting I/2014. Structure of sample in the Third Morphological Group – flakes and waste (972 specimens); 2. Cutting I/1980. Structure of sample in the Third Morphological Group – flakes and waste, in terms of size (522 specimens); 3. Cutting I/2014. Structure of sample in the Third Morphological Group – flakes and waste, in terms of size (972 specimens); 4. Cutting I/1980. Weight structure of flint material from sample in the Third Morphological Group – flakes and waste, in terms of size (785 specimens). Prepared by D.H. Werra.

Fig. 9 – (opposite page) Wierzbica 'Zele', Radom district (Poland), structure of flint materials.
1-4: a. First Group: Natural nodules and their large fragments, roughouts, precores and cores; b. Second Group: Blades and their fragments; c. Third Group: Flakes and waste; d. Fourth Group: Implements;
1. Cutting I/2014. General structure of sample in the four morphological groups (915 specimens);
2. Cutting I/2014. Weight structure of flint material in the four morphological groups (915 specimens);
3. Cutting I/1980. General structure of flint material from sample in the four morphological groups (998 specimens); 4. Cutting I/1980. Structure in terms of weight of flint material from sample in the four morphological groups (998 specimens); 5-8: a. complete flakes; b. specific flake types; c. microflakes and chips; d. waste; 5. Cutting I/1980. Structure of flint material from sample in the Third Morphological Group – flakes and waste (785 specimens); 6. Cutting I/2014. Structure of flint material from sample in the Third Morphological Group – flakes and waste (972 specimens); 7. Cutting I/1980. Weight structure of flint material from sample in the Third Morphological Group – flakes and waste (785 specimens); 8. Cutting I/2014. Structure of flint material from sample in the Third Morphological Group – flakes and waste (972 specimens). Prepared by D.H. Werra.

2. Both inventories have fewest specimens from Group IV: Tools – below 1 %;
3. In the material from Cutting I/1980 there was a small number of blades and their fragments (group II) – 4.37 %, and in Cutting I/2014 the amounts were even smaller – 2.2%
4. In the material excavated in 1980 the First Morphological Group comprised 10 %, while in 2014 four items were found, including one tool, making up 0.4% of the whole inventory, which

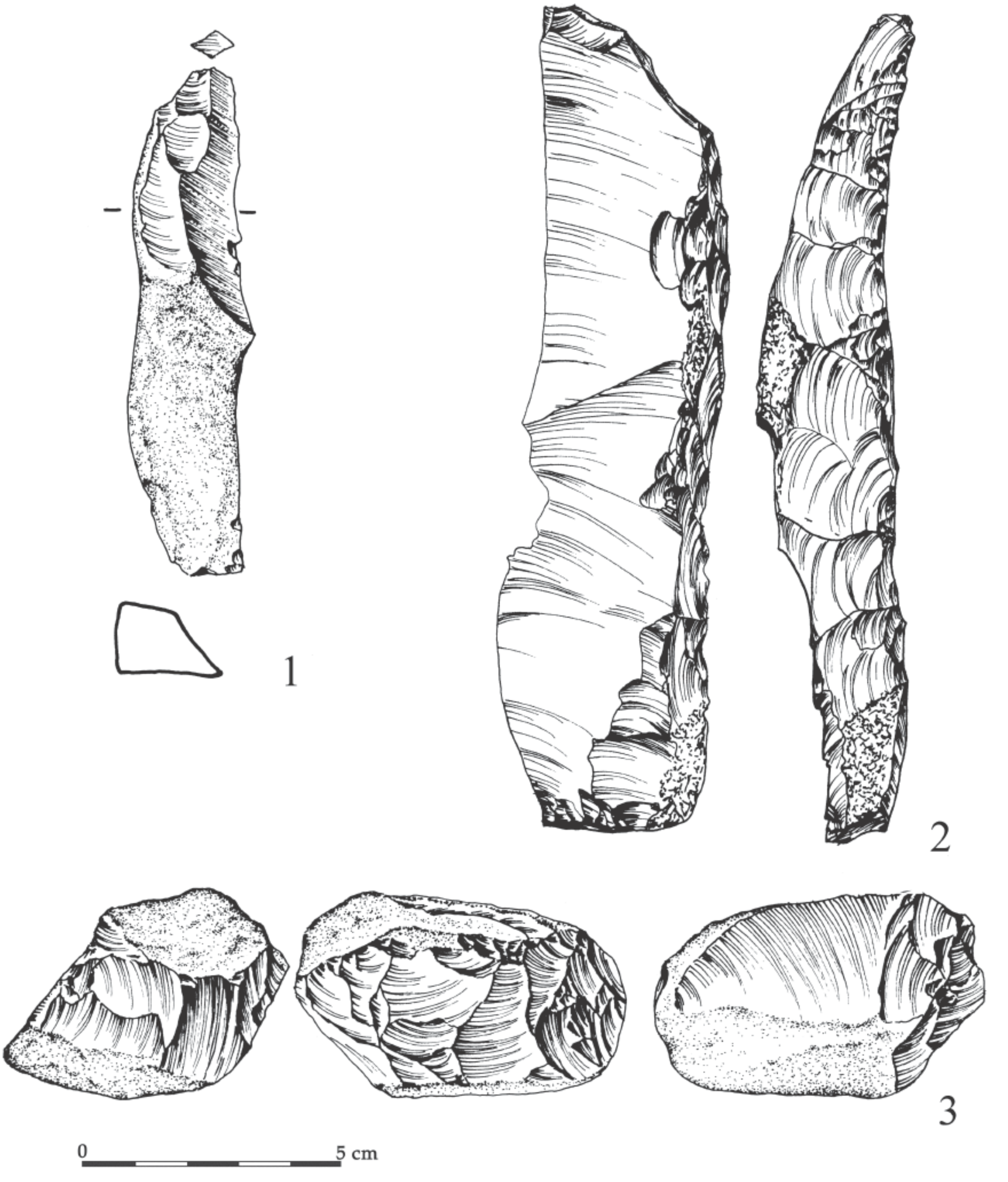


Fig. 11 – Wierzbica 'Zele', Radom district (Poland). Flint artefacts from the flint mine site. 1. Waste blade; 2. Backed blade of 'Zele' type; 3. Paracore. Drawing by E. Gumińska (1, 3) and I. Niewiadomska (2).

illustrates in this case the influence of small fractions of material on the image of its structure and, more widely, the necessity of comparing the inventories collected in the same way with the same or at least similar precision;

5. In terms of weight only group II was similar in both years: I/1980 – 1.7 % and I/2014 – 1.07 %
6. In material from Cuttings I/1980 and I/2014, group III has the largest percentage share in terms of weight. However, its internal structure is completely different. In Cutting I/1980, only large, medium and small flakes were registered. Microflakes and chips were not collected. Thus, the smallest specimens had a diameter of up to 20 mm. In Cutting I/2014, small flakes, microflakes and chips predominated, so the smallest collected specimens had a diameter of less than 10 mm.

7. In Cutting I/2014 medium flakes predominated in terms of weight (38 %), though being few in number, in second place were small flakes (42 %) and then large – 15 %. Microflakes, although numerous, by weight constituted only 5 % of the inventory.

6. On the morphology of artefacts

Among the artefacts associated with the 'Zele' mine are common flint flakes and waste, early bifacial axe roughouts and rare blades (Fig. 11:1). Very rare but important are backed knives of the 'Zele' type (Fig. 11:2) made from large blades or flakes (LECH, 1984, p. 195, 1997b, p. 96-97; LECH *et al.*, 2011, p. 114-115). Fresh analyses of flint materials from earlier excavations of the 'Zele' mine brought to our notice the presence of a group of artefacts which is difficult to interpret in the light of what we know so far about the use of flint by farming communities and in the light of our rationality. The group includes fragments of flint nodules worked by flint knappers seemingly without any useful purpose. Most of the specimens seem to qualify as cores but with closer analysis in most cases it is not possible to determine what might be the aim of exploiting such cores. Sometimes, one might conclude that the knapper's objective was to destroy the piece of flint he was working.

Professor Oliva had made similar observations with reference to late flint knapping when describing prehistoric mining in the 'Krumlovský les' in Moravia (OLIVA, 2010, p. 266 and others; OLIVA, 2011, p. 99-106). It would seem that what we have here is flint mining and knapping for partly ritualistic purposes, with limited practical use, maybe related to an ancestral cult (OLIVA, 2010, p. 294-302, 2011, p. 104-106; see LECH, 1997a, p. 110-112, 1997b, p. 96-97). In the light of studies of the material from the 'Zele' mine carried out in recent years, this explanation seems most convincing. The specimens treated in this way by knappers are not in fact cores but 'paracores' and such a category of artefacts can clearly be distinguished among the 'Zele' flints (Fig. 11:3). How these two completely different tendencies in flint working are related to each other, whether they are contemporaneous or from different periods, we cannot as yet explain.

7. Final remarks

Wierzbica 'Zele' was the first European flint mine dated exclusively to the entire Bronze Age, from its early to late period. What in the first half of the 1980s was a surprise and aroused doubts, was confirmed by excavations in the following years.

There are indications that towards the end of the Bronze Age flint mining served symbolic purposes and also for preparation of ordinary and sophisticated flint tools (LECH, 1984, p. 198-200; LECH *et al.*, 2011; OLIVA, 2011, p. 104-106; LECH *et al.*, 2015; LECH & WERRA 2018, p. 580-581). This is probably the meaning of the characteristic 'Zele' type knives, whose range of occurrence is much wider than initially thought. The presence of such backed knives is also associated with the ritual zones of southern Scandinavia (HÖGBERG, 2009, p. 263; MASOJĆ & BECH, 2011).

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The Neolithic Flint Mines of Les Marais de Saint-Gond and La Côte des Blancs (Marne, France)

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Abstract

The Côte d'Île-de-France, in particular around the Saint-Gond Marshes, is well known for numerous collective burials and notably for its hypogea. Eighteen flint mines have also been excavated there during the nineteenth or at the beginning of the twentieth century, or have more recently been detected by aerial photography. Five mining areas have been identified. The excavation of Vert-la-Gravelle 'La Crayère' concerns one of these sectors. These excavations have discovered three trenches and four shafts for flint exploitation. The flint of Saint-Gond has been geologically and petrographically studied in order to characterise the micro-facies.

In the same region, the presence of these numerous flint mines and 120 hypogea, five gallery graves, eight earthfast polissoirs and hundreds of knapping workshops suggest the presence of a new mining complex in the Saint-Gond Marshes. The study of this sector opens many new perspectives concerning the regional distribution of flint, the quantitative estimation of flint exploitation surface area and the study of territorial organisation.

Keywords: Marne, Saint-Gond, Late Neolithic, flint mines, knapping workshop, hypogeum, aerial photographs.

Résumé

Le secteur sud-est de la Côte d'Île-de-France, et notamment la région des Marais de Saint-Gond, a livré de très nombreuses sépultures collectives en hypogées, mais aussi 18 minières de silex fouillées au XIX^e^ ou au début du XX^e^ siècle. Plusieurs autres minières ont été récemment détectées par photographie aérienne. Cinq secteurs miniers ont été identifiés. L'un d'eux a fait l'objet d'une fouille sur le site de « La Crayère » à Vert-la-Gravelle, où trois tranchées à ciel ouvert et quatre puits pour l'extraction du silex ont été mis au jour. Le silex de Saint-Gond a fait l'objet d'une caractérisation pétrographique détaillée des micro-faciès.

La présence de ces nombreuses minières de silex situées dans une région comprenant plus de 120 hypogées, cinq allées couvertes, huit polissoirs fixes et des centaines d'ateliers de taille permet d'évoquer la présence d'un nouveau complexe minier. L'étude de ce secteur ouvre de nombreuses perspectives concernant la diffusion de ce silex à l'échelle régionale, l'estimation des surfaces d'extraction du silex et l'étude de l'occupation du territoire.

***Mots-clés** : Marne, Saint-Gond, Néolithique récent, mines de silex, atelier de taille, hypogée, photographies aériennes.*

1. INTRODUCTION

In the archaeological community, this region is better known under the name of the Petit Morin Valley (*vallée du Petit Morin*), rather than the Saint-Gond Marshes (*région des Marais de Saint-Gond*). Nevertheless, the Neolithic occupation of this region extended beyond the valley of the Petit Morin River, which originates in the marshes. Most of the Neolithic sites are located on the hills in the northern part of the Saint-Gond Marshes. The area is notable for the numerous hypogea that have been excavated at the end of the nineteenth century and at the beginning of the twentieth.

Numerous flint mines have already been identified in these regions (MARTINEAU *et al.*, 2014). Before this synthesis, very few references were available in the scientific literature concerning the flint mines of the Saint-Gond Marshes. Some data concerning a few of these sites is accessible in the excellent synthesis of Gerd Weisgerber (RODEN, 1999a, 1999b), but many descriptions are not exact, with several minor errors. The flint mines covered a large area, which comprises not only the Saint-Gond Marshes, but also a large part of the south-eastern cuesta of the Île-de-France, and notably the Plateau de la Brie champenoise and the Côte des Blancs areas.

Many of these mines were discovered between 1872 and 1941. Few of them have been excavated; the majority have only been detected by aerial photography. Many have also been verified or detected by walk-over surveys, and one of them has recently been excavated. Close to these flint mines, many other sites (collective burials, knapping workshops, earthfast polissoirs, etc.) have been also discovered, constituting a large mining complex. It appears that the level of flint mining in this region has been largely under-estimated until now.

Since 2011, a research programme has developed. Forty-five colleagues are involved in a multidisciplinary research group, focussing upon the Neolithic of the 'Saint-Gond Marshes' and the Côte des Blancs area. This research programme consists of aerial prospection, walk-over surveys, site-mapping, excavations, artefact studies, geological investigations and palaeoen-vironmental analyses. These researchers are from several institutions: the National Centre of Scientific Research (CNRS), the Universities of Burgundy/Franche-Comté, Champagne-Ar-denne, Lyon and Paris, and the French National Institute for Preventive Research (INRAP).

2. CONTEXTS

2.1. Previous research

The Saint-Gond Marshes are renowned for the numerous important discoveries of Joseph de Baye. Between 1872 and 1886, this young archaeologist discovered more than a hundred hypogea there. Later, more than twenty other hypogea were discovered in this area, notably by Augustin Roland and Pierre Hu, and later by André Leroi-Gourhan, Bernard Chertier and Guy Mazières. More than 150 hypogea have been discovered in the Marne department, distributed in 15 necropolises. These collective graves are commonly dated to the Late Neolithic period (between 3600 and 3000 cal BC).

J. de Baye discovered two flint mines at Coizard 'La Haie Jeanneton' in 1872, and at Vert-la-Gravelle 'La Crayère' in 1873. A. Roland, in 1907, and André Brisson, in 1938, also discovered other flint mines. At that time, archaeologists were not very interested in flint mines. Before the development of lithic technology studies, the abundance of knapping waste in the pits, the absence of beautiful objects, and above all the difficulty of this type of excavation limited interest in such finds. So, unfortunately, these few excavated mines have not been as well documented as the hypogea.

2.2. Archaeological context of the region

An inventory of Neolithic sites, based upon archives and literature searches, completed by new walk-over and aerial surveys, has been carried out in this region. The database now comprises more than 300 Neolithic sites, whether explored or simply identified, notably concentrated in the north of the Saint-Gond Marshes. Such a concentration is very impressive for this period, and constitutes a good framework to study the social and territorial organisation of Neolithic societies in this area. Discoveries in this region include more than 120 hypogea (in 15 hypogeum necropolises), five gallery graves, three settlements, height earthfast polissoirs, several dozen knapping workshops, and at least 18 flint mines (Fig. 1). The map shows the main settlements, hypogea, gallery graves, flint mines and workshops, which are principally concentrated in the northern part of the Saint-Gond Marshes.

Eighteen flint mines have been identified in this area. They are distributed along the south-east of the Côte d'Île-de-France, on the hill slopes, which provide easy access to the flint outcrops. Five mines have been excavated, and others have been detected by aerial photographs or by pedestrian surveys. Eight zones can be highlighted: Villevenard with five mines, Congy with three mines, Coizard with two mines, Vert-la-Gravelle, on the eastern slope of Toulon hill, with five mines, and Loisy-en-Brie, Givry-lès-Loisy, Vertus and Courjeonnet, with one flint mine each. Many other potential sites have been detected but have not yet been confirmed as flint mines through surveys or excavations.

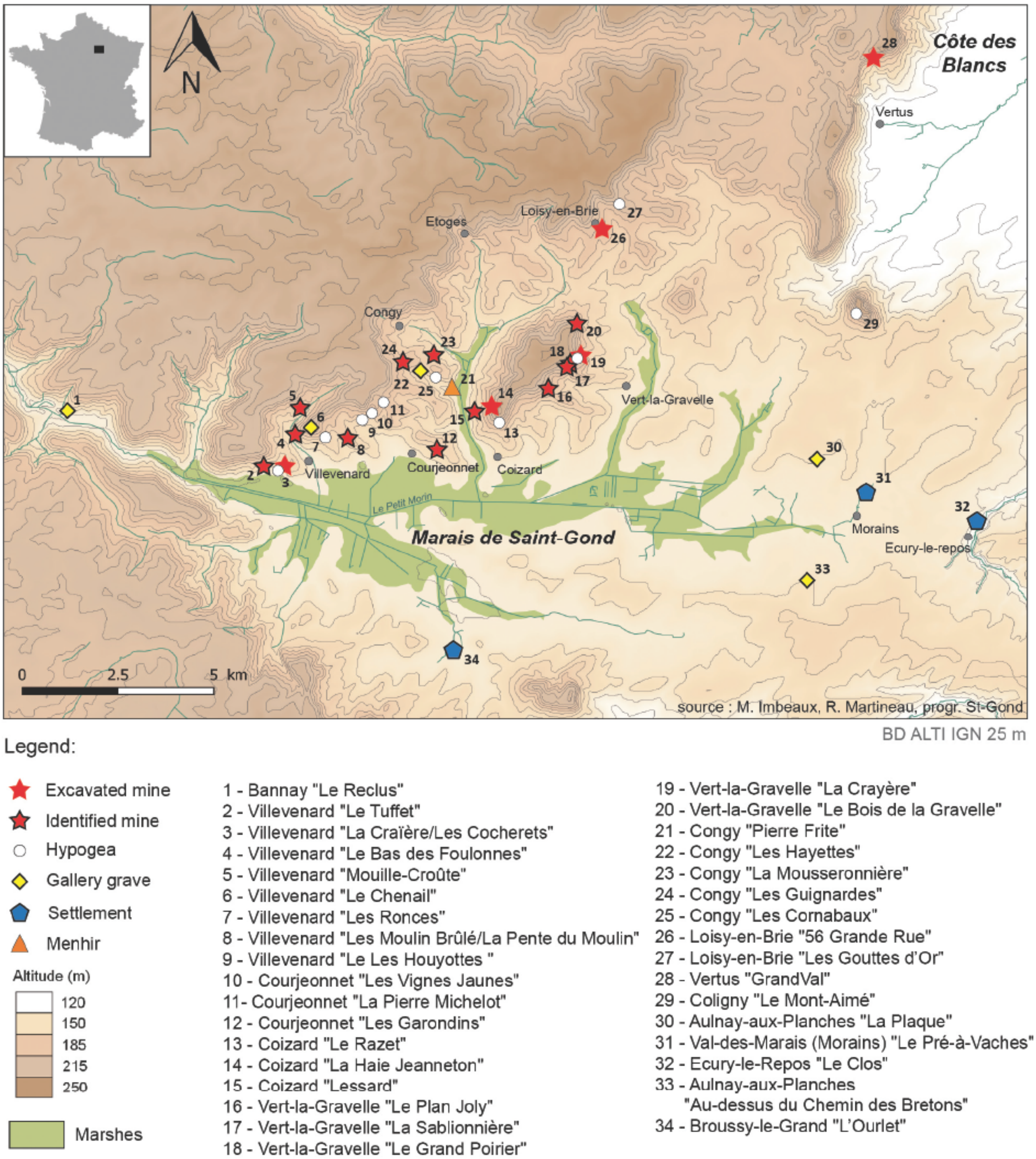


Fig. 1 – Location of the main Neolithic sites around the Saint-Gond Marshes. CAD M. Imbeaux.

All periods of the Neolithic are represented in this region. The beginning of the Neolithic is known only by a very important single burial attributed to the Linear Pottery Culture, discovered in Vert-la-Gravelle (Vert-Toulon) 'Le Bas des Vignes' (CHERTIER & JOFFROY, 1966; CHERTIER, 1988). The Middle Neolithic period is also documented in Broussy-le-Grand 'L'Ourlet'. Most of the Neolithic sites in this region are attributed to the Late Neolithic period (phase 1), dating between 3500 and 3000 cal BC. All the collective burials of this region, notably the hypogea and gallery graves also date from this period.

The chronological question is very different for the flint scatters observed in the fields compared to the flint mines. Detected by walk-over or aerial surveys, most of these sites are presently undated. Mines may occur over a long period of time, between 4700 and 2300 cal BC. However, the flint scatters discovered in the fields probably date from the Neolithic period.

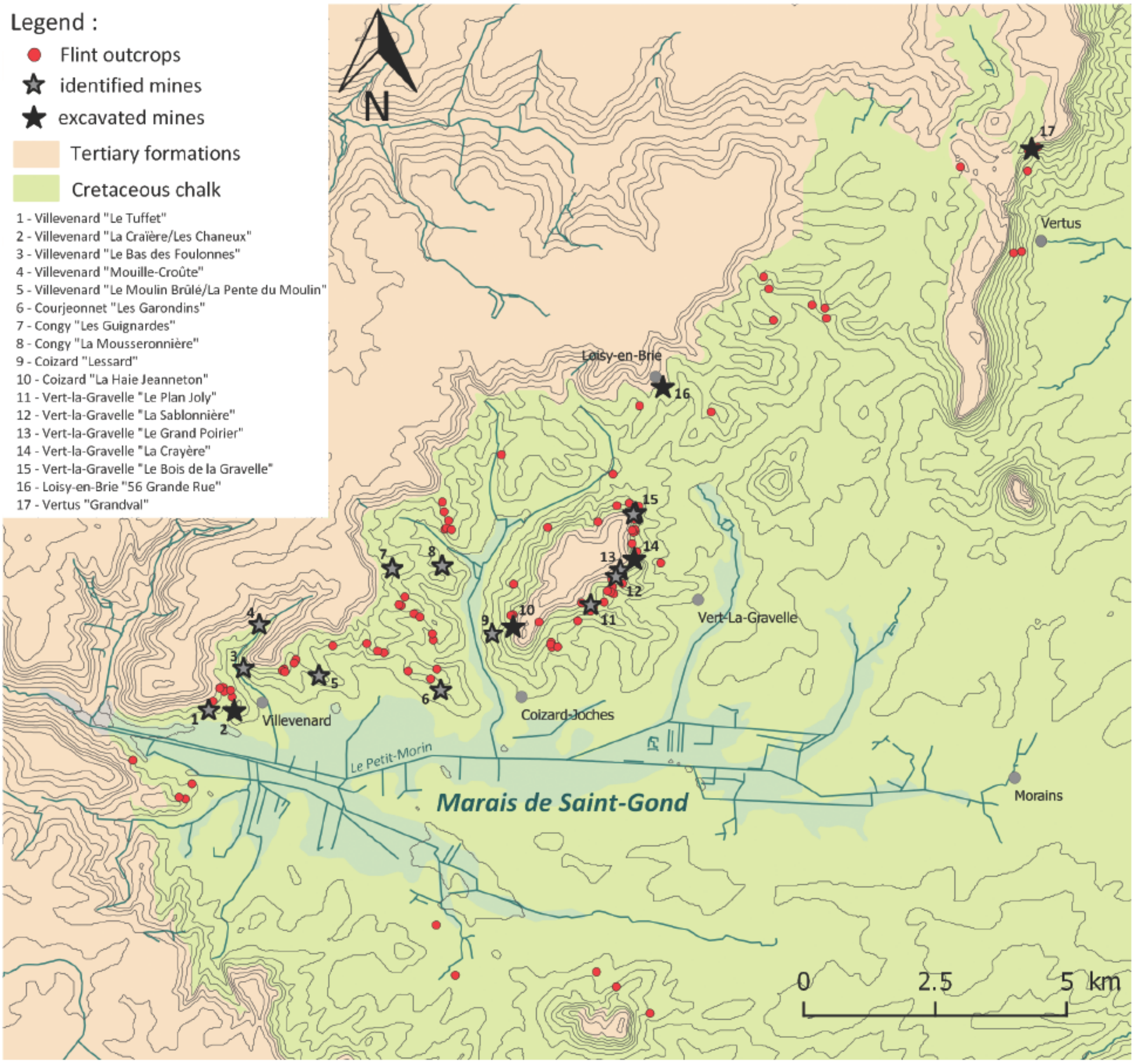


Fig. 2 – Location of the flint mines and the natural flint distribution in the Saint-Gond Marshes. CAD M. Imbeaux.

These flint spreads are usually interpreted as 'knapping workshops' although in the absence of excavations, the actual function of these sites (artisanal or domestic) is generally unknown.

The dense concentration of Neolithic sites, mainly attributed to the Late Neolithic period, comprising knapping workshops, earthfast polissoirs, settlements, but also numerous collective burials, allows us to define a new 'mining complex', according to the definition given by Pierre-Arnaud de Labriffe and Dominique Thébault (DE LABRIFFE & THÉBAULT, 1995, p. 49). According to this definition, the question now is to discover whether this high concentration of sites is due to flint exploitation or if the settlement pattern is not in fact directly associated with the presence of this abundant resource.

2.3. Geological context

The Saint-Gond Marshes are found along the eastern side of the cuesta of the Île-de-France, topography created during the Quaternary (HATRIVAL *et al.*, 1988). It followed the substantial erosion of the Cretaceous chalk, which was not protected by Tertiary formations during several successive glaciations and interglacial periods. The erosion of the chalk hills revealed the flint on the slopes, providing access to the raw material.

The chalk was formed in the Late Cretaceous, 75 million years ago, during the Late Campanian (ALCAYDE *et al.*, 1980). It contains dark brown and black flint. Knowledge of geological data is important for mapping the siliceous raw material sources and the knapped flint distribution in this region.

In order to identify the extension of the flint outcrops and to characterise the diversity of the flint, five walk-over surveys have been carried out in this region since 2012 (MARTINEAU *et al.*, 2016). Taking into account the ancient Neolithic discoveries and current geological knowledge, the potential of flint resources for prehistoric flint exploitation is very high for this region. The Butte de Toulon has been entirely prospected and many other sectors (Chouilly, Loisy-en-Brie, Villevenard, Oyes) have been explored to identify lithic resources. Several flint seams are visible in the chalk outcrops. At least 110 flint outcrops have been precisely located and sampled to determine the sedimentary facies (Fig. 2).

The outcrop located at Vert-la-Gravelle 'La Crayère' shows a high concentration of nodules in a shallow sub-horizontal flint seam (MARTINEAU *et al.*, 2016; Fig. 3). These nodules measure on average 50 cm long and can reach up to 80 cm. Two flint seams have been identified at this site, but eight or nine seams could be stratified within the hill.

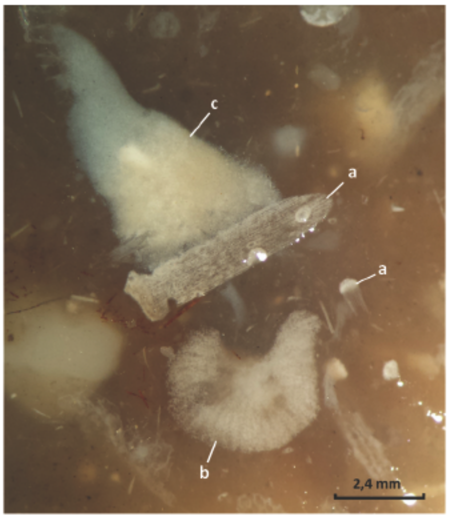
Fig. 3 – A flint outcrop in Vert-la-Gravelle (Vert-Toulon) 'La Crayère' (Marne, France), close to the Neolithic site. The nodules have been broken by the exploitation of the chalk in this stone quarry located close to the Neolithic site. Photo R. Martineau.

The flint of Saint-Gond ranges from black to dark brown with a white cortex. We can find it as irregular nodules or as tabular deposits. The nodules are suitable for making blades, whereas the tabular flint is not easy to flake because they are faulted and recrystallised. Macroscopically, it resembles the Maastrichtian flint from the Belgian Dutch region but microscopically it is possible to distinguish the flint of the Saint-Gond Marshes from that of the Belgian Dutch region by its sedimentary facies (IMBEAUX *et al.*, 2018). The petrographic facies of Saint-Gond has been determined and subdivided into five sub-facies. Each of them characterises a sedimentary environment, which constitutes a precise description for the determination of the raw material sources (SÉRONIE-VIVIEN, 1987; FABRE, 2001; AFFOLTER, 2002; DELVIGNE *et al.*, 2016, IMBEAUX *et al.*, 2018).

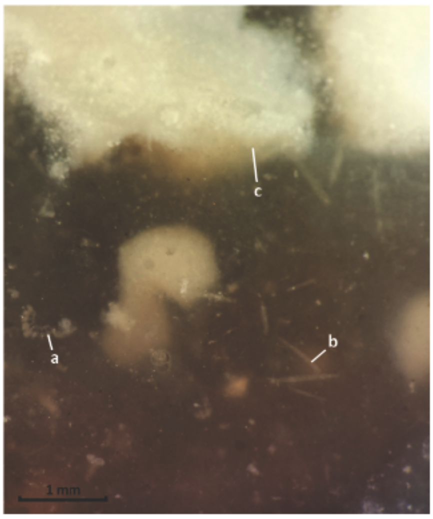
The sedimentary environments of the sub-facies of the flint have been determined on raw material from five excavated mines. The Saint-Gond facies is characteristic of a shallow marine environment, an open carbonate platform comprising many bioclasts, like sponges, sea urchin spines, bryozoans and foraminifers.

Within this study, it appears that it is possible to distinguish each mine by slight differences in the Saint-Gond flint facies. On the basis of these differences, five flint sub-facies have been distinguished. Each of them has been called by the name of the site, corresponding to each mine. These differences between each mining sector represent the variation in space and time of sedimentary environments in the Cretaceous sea (Fig. 4). Over time the sea level has fluctuated, which has impacted upon the sedimentary environment. For example, a small difference in depth can influence the currents, temperature or chemistry of ocean water. These characteristics directly impact the marine fauna and the sedimentary processes, which can then be seen by the aspect (notably their state of preservation) of the fossils and other clasts preserved in the flint.

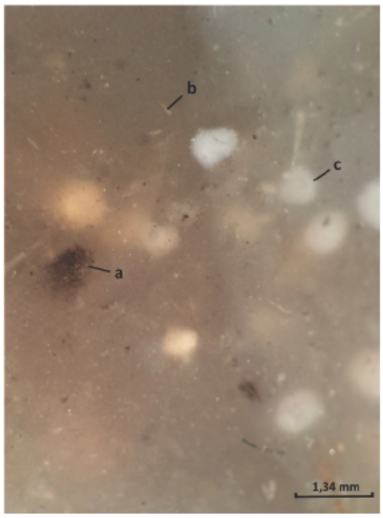
The analysis of the sedimentary facies of the flint raw material and of the archaeological artefacts discovered in the Neolithic sites of the region, allows us to link the mining activity with the



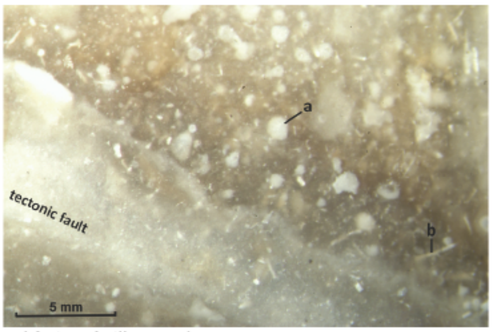
subfacies of Coizard
(a) sea urchin spine, (b) sea urchin fragment
(c) sponge fragment



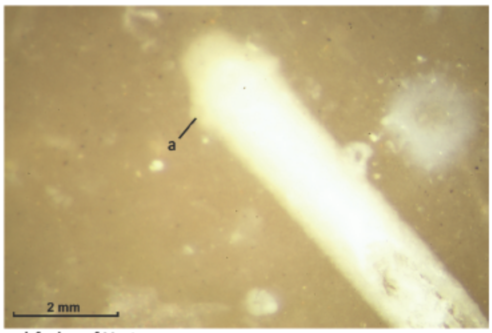
subfacies of Vert-la-Gravelle
(a) sea urchin spine, (b) sponge spicule, (c) sponge fragment



subfacies of Loisy-en-Brie
(a) organic matter, (b) sponge spicule
(c) micritised foraminifer



subfacies of Villevenard
(a) micritised foraminifer, (b) sponge spicule



subfacies of Vertus
(a) sea urchin spine

Fig. 4 – Microscope photographs of the principal clasts of the five subfacies identified.
Photos M. Imbeaux.

other sites, like settlements or collective burials. These investigations will reveal the practices and habits of acquisition and the distribution of flint by Neolithic groups.

The Saint-Gond flint has been recorded at five collective burials and two settlements dated to the Late Neolithic period (IMBEAUX, 2016; IMBEAUX *et al.*, 2018). Saint-Gond flint constitutes the major part of the lithic resources in these sites. Each of the sub-facies has been identified in each Neolithic site. These first results show that the mines were exploited during the Late Neolithic period. Each mining sector analysed provided a source of raw material for the local communities, who did not only exploit these mines. Other sources have been identified at the archaeological sites. More interestingly, a network of lithic exchange seems to have existed between the sites (and maybe between the groups or communities) of this region.

3. The flint mines of La Butte de Toulon

The sector of the eastern slope of La Butte de Toulon was intensively exploited for flint mining during the Neolithic. Ancient discoveries, recent walk-over surveys, and new excavations in this sector have discovered at least four large mines.

3.1. The site of Vert-la-Gravelle 'La Crayère'

The site of Vert-la-Gravelle 'La Crayère' (Vert-Toulon, Marne department) is located on a steep slope, on the eastern side of the Toulon hill, in a wood near the Champagne vineyard. Since 2012, excavations have explored Vert-la-Gravelle 'La Crayère'. This site was first identified through the discovery of a hypogeum, around 1870, which led to the discovery of two other hypogea and a flint mine located at the same place, both excavated by J. de Baye in 1873.

The mining structures were not previously visible, because they were buried beneath a thick layer of topsoil. Consequently, their state of preservation is very good. Two contemporaneous trenches (Trench 1 and 3) were aligned along the flint seam and separated by two bell-shaped shafts. Behind and above Trench 3 lay four hypogea, which have been previously excavated. Trench 3 measures 25 m long. The trench was filled with sediment composed of a mixture of chalky silt and chalk (1.2 m thick). In the Trench 1 and 3, the miners have excavated the chalk as far as possible to exploit the flint. But this exploitation system has a limit: the quantity of chalk sediment to extract.

Trenches 1 and 3 were oriented east-west along the flint seam. The negative impressions of the nodules in this trench showed that the same flint seam had been exploited on two levels, demonstrated by the dispersion of the nodules and slabs in this sector. Several niches and negative impressions left by flint extraction are clearly visible in the trenches. The dimensions of the nodules and the slabs can be deduced from these impressions.

The nodules surviving in the chalk have been recorded precisely to determine the altitude of the flint seam. The impressions of the nodules that were removed from the chalk by the miners have also been recorded (MARTINEAU *et al.*, 2016). This data indicates that the seam is located at an altitude between 190.8 and 193.8 m. The largest nodules lie in the central part of the seam, whereas the smaller nodules are located in the lower and the upper parts.

Thirty nodules have been sampled to determine the variation of the sedimentary facies in the site. The sedimentary facies, 65 m long and 3 m thick, is totally homogenous. Some tectonic faults and joints were also locally filled by flint, which fragmented into plates parallel to the fractures. These appear only at the same altitudes as the nodules. In the layers of chalk that do not contain flint, the fractures do not show such silicification. These plates have the same sedimentary facies as the nodules but they are lightly more recrystallised. Furthermore, some nodules have been observed which were partially deformed into plates. This indicates that they were not due to the circulation of fluids along the fault or the joints, but rather that the plates were originally ancient nodules which were deformed by tectonic movements.

Two shafts were unfortunately excavated by J. de Baye in 1873 and rediscovered during our excavations. Shafts 1 and 2 are bell-shaped shafts (in German *duckelbau*) and measure 2 m wide at the mouth and 2.4 m deep (Fig. 5). These shafts are linked by a passage supported by a pillar. The pillar mining technique seems to have been used systematically in the shafts, and sometimes in the trenches.

Two other shafts had been dug close to Trench 1. Shaft 3 was unfortunately also previously excavated by J. de Baye, but one part of the filling had been left untouched by the excavators. This shaft has to be considered as a prospecting pit, because the flint seam was not reached in this case. The fill of Shaft 4 was preserved and its excavation is currently underway. Shaft 1 is linked to Trench 1 by a short passage, indicating that the two structures were probably contemporaneous (Fig. 6).

At this site, the system of flint exploitation combines several types of structures: shallow pits, bell-shaped or cylindrical shafts, and trenches. All of these forms of extraction seem to be contemporaneous. Amongst the diversity of flint mines in Europe, the system of digging by trenches discovered here seems to be original. Moreover, the site of Vert-la-Gravelle 'La Crayère' is absolutely exceptional because of the presence of a hypogeum necropolis dug into a pre-existing flint mine. Four hypogeum corridors were found in the filling of Trench 3. This arrangement gives the impression of having been very well organised, the corridors being placed according to and following the morphology of the trench.

Stratigraphic observations clearly show that the hypogeum corridors were dug after the mine trench was abandoned. One of the main questions is to reconstruct the process of the successive occupations, and notably the chronology of the site. Six radiocarbon dates have been obtained for Trenches 1 and 3. They have been obtained from charcoal (excluding the 'old wood'), and on antler fragments. These six dates correspond exactly to the same period, between 4350 and 4000 cal BC, compatible with the Middle Neolithic phase II. Culturally, the mine could correspond to the Michelsberg or to the Northern Chassean cultures

Hypogea are generally attributed to the Late Neolithic period, dated between 3600 and 3000 cal BC. This period is 500 years later than the flint mine of Vert-la-Gravelle 'La Crayère', which corresponds perfectly with the stratigraphic observations. Because of the rarity of pottery

Fig. 5 – Vert-la-Gravelle 'La Crayère'. Interior of the bell-shaped shafts 1 and 2.
View of Pit 2 in the direction of Pit 1. A pillar was left between the pits, in order to buttress the mining area. Some retained pillars are also observable.
Photo R. Martineau.

Fig. 6 – Vert-la-Gravelle 'La Crayère'.
Trench 1 at the end of the excavation campaign. We can see the passage with Pit 1 and several niches and negative imprints left by the extraction of flint nodules.
Photo R. Martineau.

in the collective graves in the north of France, the hypogea of this region are not yet culturally defined. To resolve the chronological question surrounding the successive phases, the fillings of the corridors and the objects discovered in the hypogeum chambers at the end of the nineteenth century need to be dated by radiocarbon analysis. Consequently, ten new radiocarbon dates have been sent to be analysed in the framework of the Neomine project (resp. Stephen Shennan, University College of London).

More than 50 antler fragments have been discovered in the mining structures, notably in Trenches 1 and 3. They are very well preserved. Some of these antler fragments were mining tools (picks or levers), while the others were probably manufacturing waste (Fig. 7). Two antler tools have a perforation, which suggests that they had a handle. Antler picks were probably not the only tools used to dig the mining structures. Long wood levers and wedges were almost certainly also used for this purpose.

Fig. 7 – Vert-la-Gravelle 'La Crayère'. Trench 3. Some antler picks, levers and debitage coming from the manufacture of tools. Photos R. Martineau.

Several thousand pieces of flint comprising cores, flakes, blade fragments and flint hammerstones have been discovered between 2013 and 2016. Two transverse arrowheads correspond culturally to the period dated by radiocarbon analysis.

It is important to note, for instance, that no workshops have so far been identified in the periphery of the mines. However, the site is very extensive and probably covers several hectares, so knapping workshops could have existed at the bottom of the hill several dozen metres from the excavations. In the coming years, trial trenching will be carried out to explore this sector and to test this hypothesis.

Many other ancient discoveries have been made in this area, close to the mine of 'La Crayère'. We know that discoveries have been made in the forest located to the south of the site, in the upper part of the hill. In this sector, a 5 m deep shaft with characteristic lateral galleries was discovered in 1938 by A. Brisson. It produced siliceous blocks, an axe fragment and a large pottery sherd (BRISSON, 1938, p. 65). Two other shafts have been excavated to the south of this site.

About 350 m from the 'La Crayère' site the shaft of Toulon-la-Montagne 'Les Marnières' was excavated by André Brisson, Pierre-Marcel Favret, Jacques Prieur and Léon Petit on 23rd April 1938 (BRISSON, 1938; LANTIER, 1943, p. 211). A 4 m deep shaft with several lateral galleries 60 cm high was dug through a very poor quality chalk. For safety reasons, these excavations were abandoned.

A second shaft is located 300 m from the previous one. The shaft of Vert-la-Gravelle 'La Belle Gueule' was excavated in 1937 by André Brisson and André Loppin (BRISSON, 1946; LOPPIN, 1937). The shaft was 2.6 m in diameter and 2.8 m deep. At the bottom, seven galleries measuring 1 m long were observed. Only flint flakes were discovered in this shaft.

3.2. The sites of Coizard 'Lessard' and 'La Haie Jeanneton'

In the sector of the eastern slope of La Butte de Toulon, a flint mine was discovered in 1872 by J. de Baye at Coizard 'La Haie Jeanneton' (DE BAYE, 1872, 1880, p. 134, 1884, p. 150-151, 1885, p. 242-244, 1888, p. 64-65). This constitutes the first discovery of a flint mine in the Saint-Gond Marshes. At this site, J. de Baye found a flint mine comprising numerous bell-shaped shafts, more than three metres deep, inter-connected by several narrow galleries. About twenty flint flakes and one core from this site survive in the de Baye collection curated in the National Museum of Archaeology at Saint-Germain-en-Laye. The flint mine of Coizard 'La Haie Jeanneton' was rediscovered in 2015 during our walk-over surveys. The mouths of the shafts are still visible today.

Very close to this flint mine, aerial reconnaissance has brought to light a previously unknown large flint mine in Coizard 'Lessard'. The crop marks are distributed over at least 40 ha. All the shafts measure 3 to 5 m in diameter and seem to be aligned east to west (Fig. 8). A large amount of knapping waste and numerous flint nodules have been observed in the fields surrounding this site.

For the moment, it is not possible to know if the flint mine of 'Lessard' belongs to the same phase of exploitation as 'La Haie Jeanneton'. In all cases, this sector appears to have been totally exploited by flint extraction. It is also useful to recall that these two flint mines are located near the biggest and best-known hypogeum necropolis of Coizard 'Le Razet', which comprises at least 37 hypogea. This hypogeum necropolis is renowned for the sculptures of axes and human figures represented into the walls of the funerary chambers.

4. The flint mines of La Butte du Chenail

At the foot of 'La Butte du Chenail', not far from the marshes, at Villevenard 'La Craïère/Les Cocherets', a flint mine was excavated by A. Roland in 1907. A series of interconnected galleries had been dug to a depth of four metres, maybe on two levels (ANONYMOUS, 1907a, 1907b). Bones and charcoal fragments were found in the fills of these galleries. At the same site, two other shallow pits, interpreted as flint extraction, have been excavated (VILLES, 1987). More recently, a flint seam has been observed on this site. Close to this flint mine, at Villevenard 'La Craïère', a hypogeum

Fig. 8 – Coizard 'Lessard' (Marne, France).
Aerial view showing hundreds of pits and shafts revealed by cropmark anomalies © Bing.

necropolis was excavated by J. de Baye. This example shows once again the spatial proximity between the hypogea and the flint mines.

At Villevenard, many other potential flint mines have been detected by aerial photography, at 'Le Moulin Brûlé', 'Mouille Croûte' and 'Le Tuffet'. Walk-over surveys have to be carried out to confirm the nature of these sites, which will open possibilities for further research.

Two dates have been obtained from charcoal: the date of Pit D ranged between 4555 and 4369 cal BC, whereas the date of Pit B lay between 3340 and 3022 cal BC. The difference between these two date ranges associated with two adjacent pits could be explained by the 'old wood effect', which was unfortunately not taken into account for these dates. For this reason, new radiocarbon analyses are underway.

5. The flint mine of Loisy-en-Brie

The flint mines are not only located in the Saint-Gond Marshes. The flint exploitation phenomenon extends to the north of this region, notably in Loisy-en-Brie, Givry-lès-Loisy and also on the Côte des Blancs to the north-east, in Vertus.

In 2012, six shallow pits were discovered in Loisy-en-Brie '56 Grande Rue', constituting the first discovery of flint exploitation in this sector. A rescue excavation was undertaken before the building of a house. Six shallow pits (under 1 m in depth) with irregular shapes (between 0.5 to 4 m long and 0.5 to 2 m wide) were excavated (MARTINEAU *et al.*, 2012; Fig. 9).

Fig. 9 – Loisy-en-Brie '56 Grande Rue' (Marne, France). A shallow pit (F) showing a niche for the extraction of flint. Photo R. Martineau.

The rescue excavations on the Loisy-en-Brie shafts delivered around 450 artefacts from the fills of the pits and niches. The assemblage is composed of 40 % of unused blocks, resulting from the first stage of testing and cleaning the raw material recovered from the pits. In fact, observations of the lithic assemblage show that the raw material was very poor quality, which justified this initial selection phase. The natural blocks and the tabular flint are all affected by a more or less continuous, poorly silicified central zone, creating areas of weakness and cavities, often problematic for knapping. The technological study of the debitage highlights the existence of two main products. Firstly, the production of bifacial pieces, probably axeheads, which have been recognised exclusively through the characteristic bifacial preparation flakes (Fig. 10). No roughly flaked axeheads or fragments have been found. Secondly, flake production has been identified, especially from the presence of cores. The morphology of some and the unipolar negatives on the flakes indicate that one of the objectives of this production was to obtain elongated flakes (Fig. 11). This type of flake production in a mining context is associated with the flint mine of Villemaur-sur-Vanne 'les Orlets' (DE LABRIFFE *et al.*, 1995), but the reduction sequence there was similar to the Levallois method and, therefore, different from that of Loisy-en-Brie. However, flake production could be linked to the Middle Neolithic phase of exploitation of this flint mine, while axe production could be more recent.

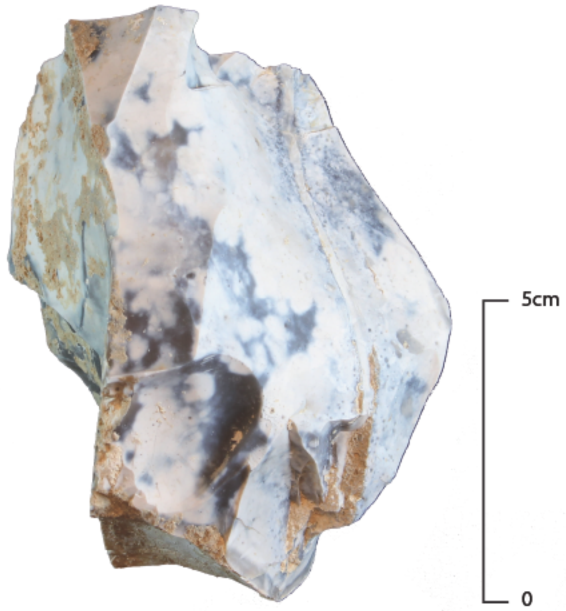


Fig. 11 – Loisy-en-Brie '56 Grande Rue'. Flake core from Pit B. Photo F. Bostyn.

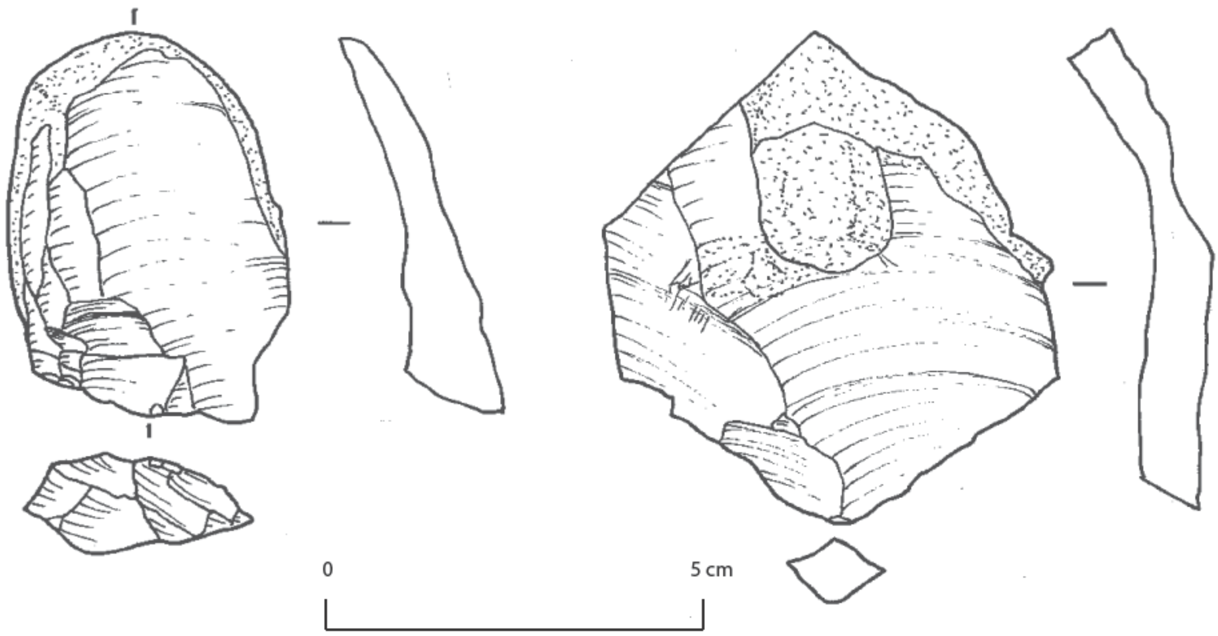


Fig. 10 – Loisy-en-Brie '56 Grande Rue'. Characteristic bifacial preparation flakes. Drawing F. Bostyn.

Loisy-en-Brie constitutes a new mining area, which was completely unknown until recently. A hypogeum, at Loisy-en-Brie 'Les Gouttes d'Or', is located 800 metres from this mine (CHERTIER *et al.*, 1994).

To the north of Loisy-en-Brie, another flint mine has been detected by the aerial photographs of Bernard Lambot. In Givry-lès-Loisy 'Part de Comté', 'Le Gros Terrier', and 'Les Champs Moreaux', numerous cropmarks suggest a very probable flint mine. This type of site has never been identified before in this area. This flint mine and that of Loisy-en-Brie attest the presence of a new mining area, located to the north of the Saint-Gond Marshes. These new flint mines greatly extend the known area of flint exploitation.

6. The flint mine of La Côte des Blancs

Several kilometres to the north-east, another flint mine was discovered in 1940, on La Côte des Blancs. A mine shaft (about 3.5 m deep) with three galleries was observed at Vertus 'Grandval' (COUTIER *et al.*, 1962; MARTINEAU *et al.*, 2014). About five kilograms of knapped flint composed of flakes, blades, a blade core and some flake cores, were associated with a calcareous fragment interpreted as a possible lamp, and a polished flint nodule, which constitute the artefact assemblage from this site, which is now unfortunately lost. This type of lamp is known in several flint mines in England and Belgium, notably in Spiennes (SOULIER, 1971; VERHEYLEWEGHEN, 1958).

At the bottom of the shaft, a skeleton was discovered, associated with three antler picks and some knapped flint. One of the three picks has been dated between 3310 and 2904 cal BC, corresponding to the transition between Late Neolithic I and Late Neolithic II. The skeleton was that of a woman who was estimated to be 40 years old (RIQUET, 1962). Unfortunately, the absence of archaeological observations from the time of discovery renders it impossible to know if the skeleton represents a burial or a mining accident. The skeleton seems to have been mislaid in the museum collection.

The date from the pick corresponds very well with the period of the hypogeum phenomenon. A very well-known hypogeum necropolis is located close to the mine of Vertus 'Grandval': this is the site of 'Les Mournouards' at Le Mesnil-sur-Oger. Two hypogea have been excavated here: the first one by André Brisson and Léon Coutier, and the second one by André Leroi-Gourhan in 1961. It was in this hypogeum that A. Leroi-Gourhan conducted his exceptional work, which marked the beginning of modern scientific grave excavations (LEROI-GOURHAN *et al.*, 1963).

7. The site of Tours-sur-Marne

Between 1836 and 1839, on the chalky slope of a Marne river bank, seven collective graves were excavated at Tours-sur-Marne (precise site unknown), in the northern stretch of the River Marne. These graves have a bell-shaped morphology resembling a shaft and were accessible by a vertical tunnel measuring 1.5 to 2 m deep. The burial chambers measured 3 m in diameter and comprise one or two narrow galleries. In these collective graves 160 skeletons were discovered. Many artefacts, such as deer antler tools, axeheads, arrowheads, blades, and ornaments were discovered in the seventh grave (NICAISE, 1876). The traditional hypothesis proposed a reutilisation of ancient flint mine shafts as collective burial sites, but this has recently been challenged (IHUEL *et al.*, 2014). This recent study interpreted these structures as hypogea because the artefacts discovered are characteristic of that type of site. However, this hypothesis does not explain the morphology of the structures nor the presence of galleries, and above all it does not make clear the use of vertical tunnels to access the graves. Access to a hypogeum is always horizontal, but at Tours-sur-Marne access was vertical. The ancient descriptions are sufficiently clear to suggest that these structures were originally flint mines. Further surveys could provide evidence of flint outcrops on this bank of the River Marne, which constitutes a necessary precondition for the presence of a flint mine.

8. DISCUSSION

Without taking into account the case of Tours-sur-Marne (located in the north of the River Marne, nearly 20 km from the Saint-Gond Marshes), the area covered by attested flint mines in Villevenard, Courjeonnet, Coizard, Vert-la-Gravelle (Vert-Toulon), Loisy-en-Brie, Givry-lès-Loisy and Vertus is extremely large. Many other probable flint mines have been detected in other areas, in Congy, Etoges and Fèrebrianges.

The radiocarbon dates obtained for the flint mines of Vert-la-Gravelle 'La Crayère', Loisy-en-Brie '56 Grande Rue' and Vertus 'Grandval' cover a large period of time. The chronology of flint mining in this area spans at least the Middle and Late Neolithic periods (Fig. 12 and Fig. 13). The oldest date, around 4500 cal BC, is associated with the pit of Loisy-en-Brie '56 Grande Rue', whereas another date for the same pit from this site corresponds to the Late Neolithic phase I, between 3300 and 3000 cal BC. Most of the radiocarbon dates at Vert-la-Gravelle 'La Crayère' are from the Middle Neolithic II, between 4300 and 4000 cal BC. These six radiocarbon dates, obtained on charcoal and antlers, are very coherent. The youngest date was obtained on an antler pick from Vertus 'Grandval', which is dated to the end of the Late Neolithic phase I and the beginning of the Late Neolithic phase II.

This broad chronology is not surprising. Some other flint mines, like Jablines 'Le Haut Château' (BOSTYN & LANCHON, 1992), Spiennes or, even nearer, the flint mines of Le Pays d'Othe (Aube), have comparable situations.

The presence of a prospecting pit (Pit 3) at Vert-la-Gravelle 'La Crayère' is unusual. Its location

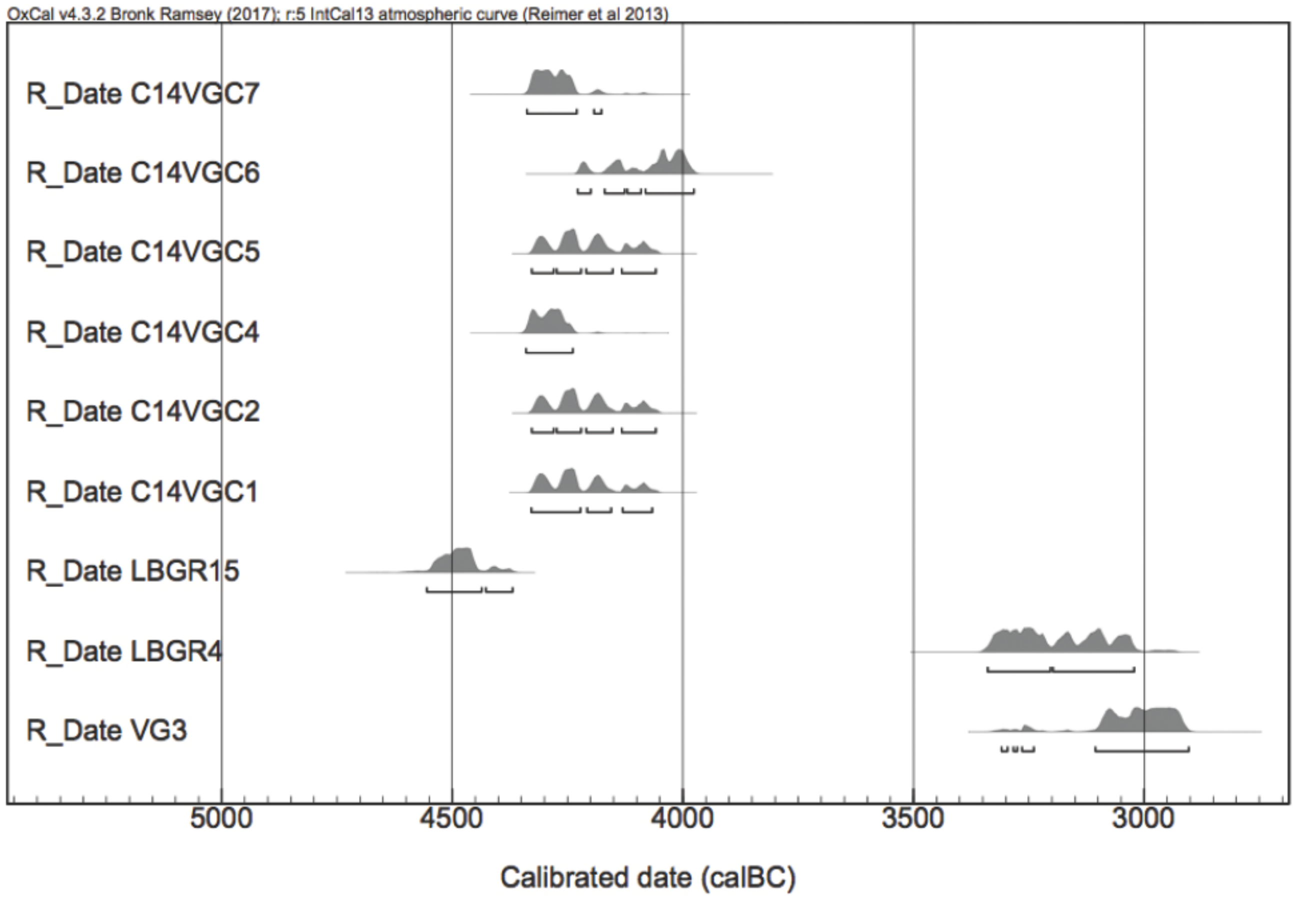


Fig. 12 – Synthesis of the radiocarbon dates from the flint mines of Vert-la-Gravelle 'La Crayère', Loisy-en-Brie '56 Grande Rue' and Vertus 'Grandval'. CAD R. Martineau.

Municipality	Locality	No sample	Lab. code	BP date	Cal BC date, 1 sigma	Feat.	m²	SU	Depth	Material dated	No object/ Remark	Old wood effect taken into account
Vertus	Granval	VG3	Poz-46885	4390 ± 40	3310-2904	-	-	-	bottom of the shaft*	deer antler		
Loisy-en-Brie	56 Grde Rue	LBGR4	Poz-53602	4465 ± 35	3340-3022	Pit D	-	3	60 cm	charcoal		no
Loisy-en-Brie	Rue	LBGR15	Poz-53603	5655 ± 35	4555-4369	Pit D	-	12	upper part	charcoal	sample n°1	no
Vert-la-Gravelle	La Crayère	C14VGC1	Ly-12461	5370 ± 30	4329-4067	TR3	-	65	40 to 100	deer antler	VGC177	
Vert-la-Gravelle	La Crayère	C14VGC2	Ly-12466	5365 ± 30	4328-4059	TR1	5	8	45	charcoal		yes
Vert-la-Gravelle	La Crayère	C14VGC4	Ly-12464	5425 ± 30	4341-4239	TR1	1	8	70	charcoal		yes
Vert-la-Gravelle	La Crayère	C14VGC5	Ly-12462	5365 ± 30	4328-4059	TR3	-	33	?	deer antler	VGC176	
Vert-la-Gravelle	La Crayère	C14VGC6	Ly-12463	5250 ± 30	4229-3977	TR1	1	8	?	deer antler	VGC99	
Vert-la-Gravelle	La Crayère	C14VGC7	Ly-12465	5405 ± 30	4339-4177	TR1 (ST4)	3	8	5	charcoal		yes

*antler pick associated with the skeleton
SU: stratigraphic unit

Fig. 13 – Radiocarbon dates from the flint mines of Vert-la-Gravelle 'La Crayère', Loisy-en-Brie '56 Grande Rue' and Vertus 'Grandval'.

between the flint seam found at 192 m altitude (corresponding to the exploitation of trenches 1 and 3) and the seam discovered at nearly 192 m altitude (corresponding to Trench 2) suggests that this mining structure was a prospecting pit. Another pit (Pit 4) currently being excavated could be a second prospecting pit. Consequently, at this site some pits may have been used to prospect for flint seams, whereas the horizontal trenches could have been dug to exploit large open-air surfaces covering several dozens of metres along the flint seams.

Some examples of this type of pit are known in England. At Easton Down (Wiltshire), in some cases no flint seam was encountered at the bottom of the shaft. This fact was interpreted as the shaft having been left unfinished (BARBER *et al.*, 1999, p. 12). Four of the six shafts excavated by J. Stone in Easton Down did not reach a flint seam. This high percentage of potentially abortive shafts might be considered unusual and seems to indicate that the depth of the seam must have been relatively straightforward to follow. In comparison to the two larger shafts which exploited the flint, the prospecting shafts were all relatively narrow (1.25 m wide), only large enough for one miner (BARBER *et al.*, 1999, p. 36-38). Similar narrow cylindrical shafts excavated at Grime's Graves have also been considered to have been dug to test for the flint seam at a known depth. Some of them were a little over 1 m in diameter and equally unsuccessful in locating the flint.

Another important point has to be taken into account: the question of any potential relationship between the flint mines and the hypogea. We can cite several examples where these two categories of sites are found in close proximity. This is the case for the flint mine of Vertus 'Grandval' located 2 km from the necropolis of 'Les Mournouards' at Le Mesnil-sur-Oger, for the flint mine of Loisy-en-Brie '56 Grande Rue', located 800 m from the Loisy-en-Brie 'Les Gouttes d'Or' hypogeum, and for several other examples in Les Marais de Saint-Gond (notably in Villevenard 'La Pente du Moulin' or 'La Craïère', in Courjeonnet 'Les Vignes Basses', in Coizard 'Le Razet', 'La Haie Jeanneton' and 'Lessard' or in Vert-la-Gravelle 'La Crayère'). In all of these examples, both the flint mines and the hypogea are systematically close to each other. It is evident that the close proximity of these sites is not sufficient to conclude that they were contemporaneous. Evidently, for the moment, this relationship has to be kept as a hypothesis, and further research is needed to test it. The question of chronology is undoubtedly the way to investigate the possible relationship between hypogea and flint mines. The radiocarbon dating of as many flint mines as possible would be the best way to establish whether these sites had been exploited during the period of the hypogea phenomenon. Spatial analysis is also planned to compare the topographic locations of the hypogea and of the flint mines, and to measure the average distances between these sites.

9. FURTHER RESEARCH

The next step in this research project will be to map the distribution of all the Neolithic sites and to quantify the area covered by flint mines in this region. Distribution maps of flint mines and the quantification of the areas involved will be possible very soon, through GIS data processing.

The other important aspect will be the detection of new flint mines. The use of remote sensing methods like LIDAR, satellite and drone images, or thermal infrared images, will be invaluable to detect new sites. Walk-over surveys will also be pursued, in order to verify any newly detected sites, and also to complete the mapping of the natural flint.

One of the other main research questions is that of the distribution of flint from Saint-Gond. The successful characterisation of the flint facies from Saint-Gond will allow us to study the diffusion of flakes and tools into the neighbouring regions (Alsace, Burgundy, Paris Basin, etc.).

At the site of Vert-la-Gravelle 'La Crayère', several opportunities are envisaged: at the end of the current excavation programme, new radiocarbon dates, lithic and antler studies, but also anthracology and geophysical analysis will all be carried out.

The detection of settlements by surveys and trial trenching is also underway in the Saint-Gond Marshes. Identifying the settlements of the miners, knappers and all those buried in the numerous collective graves constitutes one of the major questions for a better understanding of the Neolithic period in this region.

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Flint mining and blade management in the Blicquy/ Villeneuve-Saint-Germain culture through the earliest mines of Normandy and Northwest France settlements

François CHARRAUD

Abstract

The discovery of the 'Foupendant' mining site at Espins (Normandy, France) offers an opportunity to throw light on the socio-economic behaviours that characterise the neolithisation of western France through the lens of Cinglais flint exploitation. This raw material is represented by blade products on the majority of sites belonging to the Linear Pottery Culture (LBK), Villeneuve-Saint-Germain (VSG) and Early Cerny cultures, particularly in Normandy and Brittany. The discovery of the Espins site allows us to identify, for the first time, the precise geographical and geological origin of Cinglais flint and the initial stages of its exploitation.

Keywords: Neolithic, Normandy, technical system, flint mines, flint tools, blades.

Résumé

La découverte de la minière de « Foupendant » à Espins offre l'opportunité de jeter un regard nouveau sur les comportements socio-économiques qui caractérisent la néolithisation de l'ouest de la France, à travers l'exploitation du silex du Cinglais. Ce matériau est présent sous forme laminaire sur la majorité des sites du Rubané, du Villeneuve-Saint-Germain et du Cerny ancien, en particulier en Normandie et en Bretagne. La découverte d'Espins nous permet d'identifier pour la première fois l'origine géographique et géologique précise du silex du Cinglais, et les premières étapes de son exploitation.

Mots-clés *: Néolithique, Normandie, système technique, minières, outils, lames.*

Espins is situated in the south of the Caen Plain, within the Cinglais area, at the interface between the Jurassic plains of western Normandy and the Armorican Massif (Fig. 1). It constitutes one of the few sources of good quality flint close to the vast Armorican territory, which is itself devoid of this resource (MARCHAND, 1999). This type of flint was used solely for the production of blades, which were manufactured using indirect percussion. This production supplied the majority of Early Neolithic settlements in western France.

The Cinglais Plateau is characterised by flint-bearing clays which are rich in good quality flint nodules. The 33 extraction shafts found during the archaeological testing bear witness to the exploitation of these nodules (Fig. 2). The extraction shafts were simple in shape (Fig. 3), without niches, nor bell-shaped room at the bottom of the shaft or galleries like those observed at Bretteville-le-Rabet or Ri (MARCIGNY *et al.*, 2011).

Blade debitage waste has been found throughout the plateau, around the shafts and within their fill deposits (CHARRAUD, 2015). The waste fragments are characteristic of a production site: their abundance contrasts sharply with the lack of finished products which would have been systematically removed from the site. Their distribution on the surface marks out the extent of a vast mining complex of approximately 30 ha (Fig. 1). The blades produced were small (between 7 and 12 cm long) and were neither transformed nor used on site. The mining site itself, and its immediate environs, have produced no evidence for other productions or for domestic occupation (ceramics, personal ornaments, domestic tools).

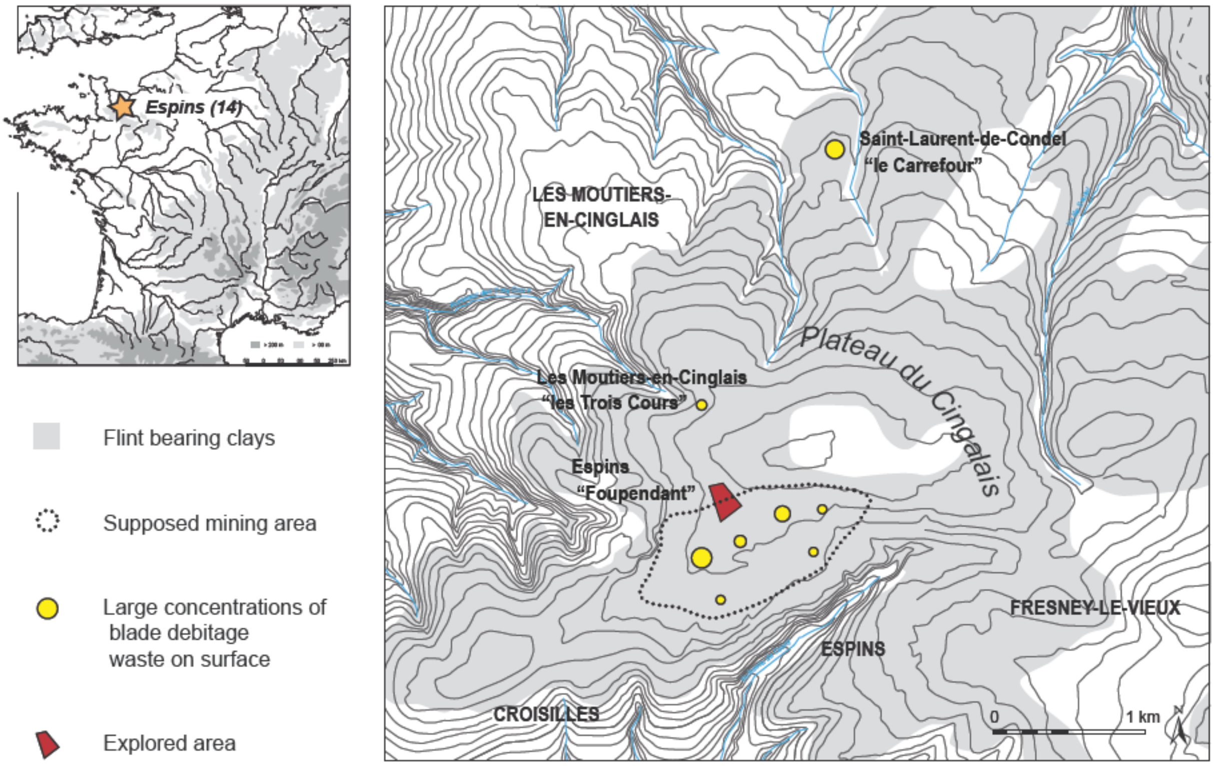


Fig. 1 – Location and topographical and archaeological contexts of the 'Foupendant' site at Espins (Normandy, France). CAD: F. Charraud.

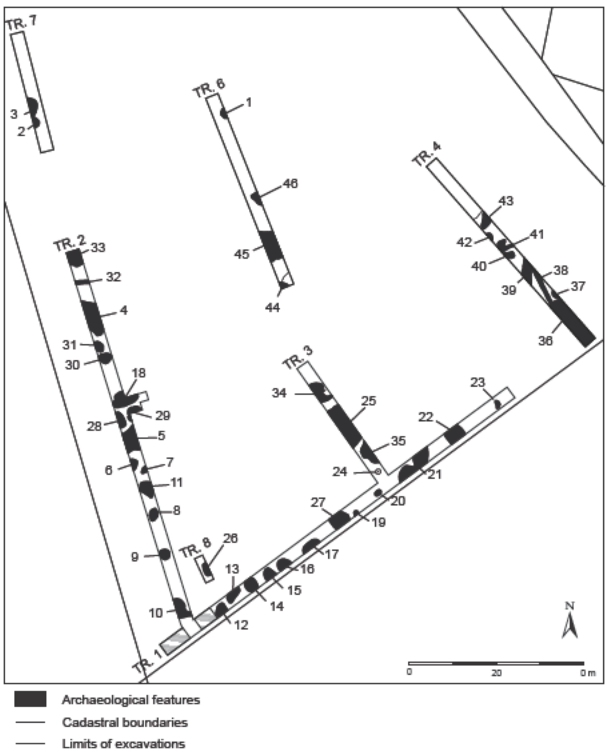
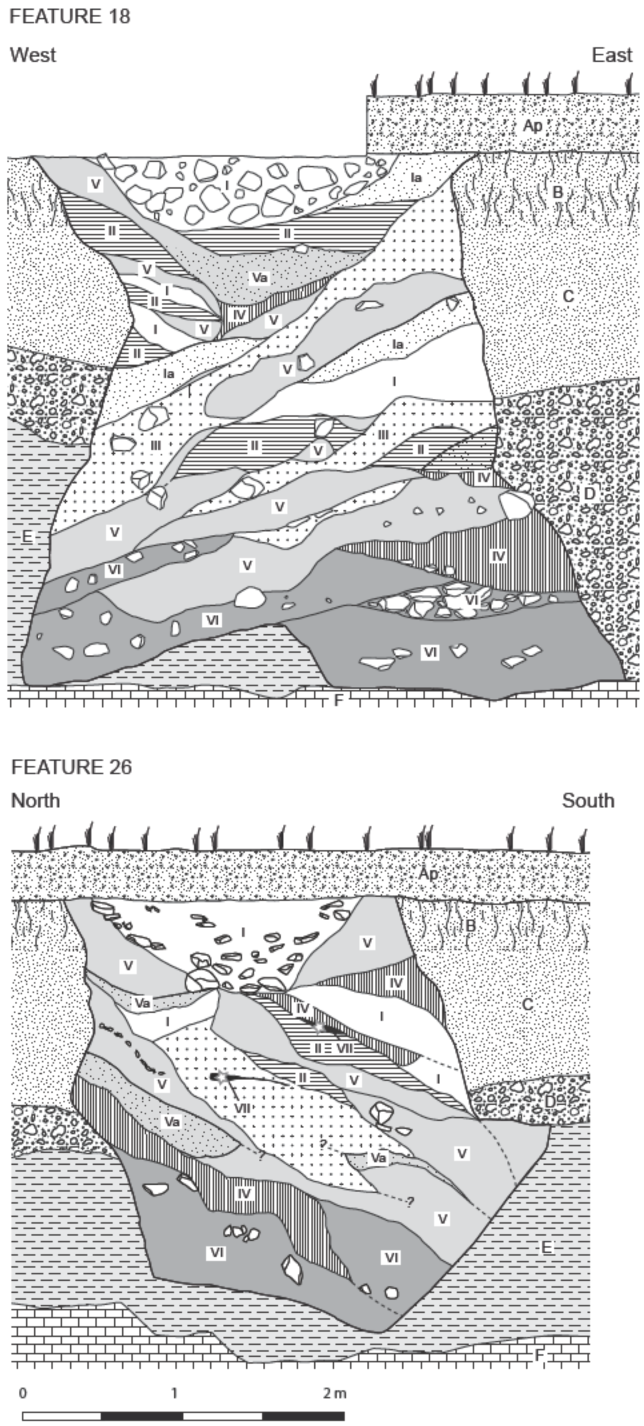


Fig. 2 – Map of archaeological testing undertaken at 'Foupendant', Espins, and location of the Neolithic remains. CAD F. Charraud.

The blade production is similar to that of LBK and Blicquy/Villeneuve-Saint-Germain sites (Fig. 4) in the Paris Basin and Belgium (BOSTYN, 1994; ALLARD, 2005; AUGEREAU, 2005). The chrono-cultural attribution of this site is based on this similarity and on two 14C dates which fall within the period between 5000 and 4750 BC. Therefore, the mining site forms part of the technical system of the Danubian Neolithic tradition which has been identified over much of north-western Europe. It is one of very few flint extraction sites known for belonging to this chrono-cultural period since the discoveries made in Central Europe.

On Villeneuve-Saint-Germain settlements, there is striking homogeneity in the products made from Cinglais flint, either in Brittany (MARCHAND, 1999; JUHEL, 2014) or in western Normandy (CHANCEREL *et al.*, 2006; GERMAIN-VALLÉE *et al.*, 2014). The flint always travels as prepared blocks or blade blanks, which are then worked and transformed on the destination site. These sites were not involved in the redistribution of the flint. The supply distance involved did not



Sedimentary context:

Ap: Organic material bearing, bioturbated grey silt, with a prismatic structure, containing artefacts from different periods, a. o. numerous struck flint.

B: Light orange clayey silt, mottled with beige-brown patches.

C: Light brown clayey-sandy silt, containing rare particles of manganese oxides (decarbonated loess).

D: Heterometric flint gravel, with indurated clay matrix, highly oxidated.

E: *In situ* red flint-bearing clay, from which the exploited flint material comes from.

F: *In situ* Bathonian limestone.

Feature backfilling:

I: Ochre-yellow homogeneous silty sediment.

Ia: *Idem* I, occurrence of little stones and flint chips.

II: Brown clayey silt.

III: Grey-light brown homogeneous clayey silt.

IV: Grey clayey silt, mottled with red clay patches.

V: Light-red clayey sediment.

Va: Idem V, occurrence of little stones and flint chips.

VI: Dark red clayey sediment.

VII: Layer rich in charcoal.

Stars: Location of 14C samples.

Fig. 3 – Stratigraphic cross-sections of two flint extraction shafts at Espins: Features 18 and 26. CAD F.Charraud.

fundamentally alter the behaviour of Neolithic people with regard to the raw material. The *chaîne opératoire* for blade production, which remained constant in Western Europe for centuries, is governed by constraints involving expertise. Consequently, we can suppose that this knowledge, and its transmission, were controlled in the same way as the lithic resources themselves and their extraction. Such constraint may have had a significant impact on distribution patterns of Cinglais flint. In this case, we may postulate the existence of itinerant flint knappers based on the fact that knapping waste is present on the Breton sites and that there are clear differences between the perceived know-how applied in Cinglais flint productions and those applied in local productions (MARCHAND, 1999). These knappers would have been the guardians of a specific technical know-how, which would explain the homogeneity of these industries throughout their distribution area and over the entire Early Neolithic period. In any case, such

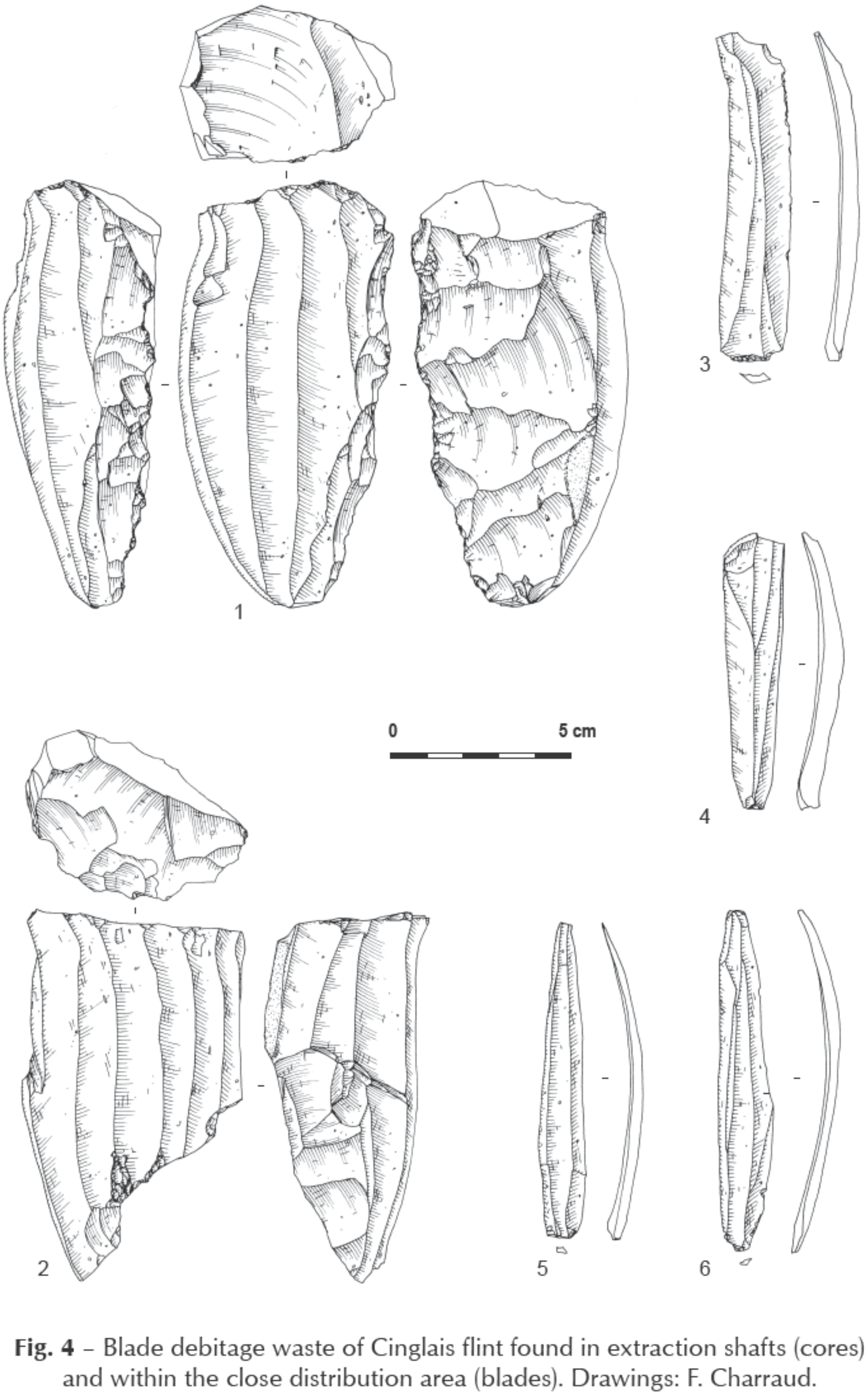


Fig. 4 – Blade debitage waste of Cinglais flint found in extraction shafts (cores) and within the close distribution area (blades). Drawings: F. Charraud.

constancy in the procurement and management of blade industries, regardless of distance from the flint source, indicates the dynamic nature of lithic raw material exploitation in this period.

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The specialisation of lithic production at the end of the Early Neolithic in Belgium; the case of the Blicquian population from Hainaut

Solène DENIS

Abstract

This paper presents some preliminary reflections on the socio-economic organisation of stone tool production of the Blicquian populations from Hainaut (Belgium, Early Neolithic). The tool production of these first agro-pastoralist communities was made by two groups of knappers with different levels of technical expertise. Indications suggest that the domestic unit was not totally autonomous when producing lithic tool blanks. In fact, blade production seems to have been organised between several villages.

Keywords: Early Neolithic, Blicquy/Villeneuve-Saint-Germain culture, lithic industries, socio-economic organisation, specialisation.

Résumé

Cet article présente des réflexions préliminaires sur l'organisation socio-économique de la production des outillages lithiques des populations blicquiennes du Hainaut (Belgique, Néolithique ancien). La production de ces premières communautés agro-pastorales repose sur deux groupes de tailleurs ne disposant pas des mêmes niveaux de savoir-faire. Un faisceau d'indices converge pour proposer que l'unité domestique ne soit pas totalement autonome pour sa production en supports de l'outillage lithique. La production de lames semble en effet organisée à l'échelle de plusieurs villages.

***Mots-clés** : Néolithique ancien, culture Blicquy/Villeneuve-Saint-Germain, industries lithiques, organisation socio-économique, spécialisation.*

1. INTRODUCTION

The Blicquy/Villeneuve-Saint-Germain culture is part of the Danubian cultures, and extends across the North of France and Belgium. Heated debate surrounds the chronological position of this culture (for an idea of the issues and challenges involved refer, for example, to BURNEZ-LANOTTE *et al.*, 2001; JADIN *et al.*, 2003; CONSTANTIN & BURNEZ-LANOTTE, 2008). Today there is a widespread consensus that the BQY/VSG followed the Linearbandkeramik (LBK), and the debate now focuses on the duration of the overlap between these two cultural entities (JADIN, 2007). Thus, the BQY/VSG constitutes the final stage of Danubian colonisation in Northern France and Belgium. Radiocarbon dating places it between 4950 BC and 4650 BC (DUBOULOZ, 2003). Periodisation based on ceramic studies prompted C. Constantin to identify three chronological stages (CONSTANTIN, 1985): an early, middle and late stage. Frequency seriation and correspondence analysis have recently been used to test the Blicquian ceramic corpus (HAUZEUR, 2008). A four-stage sequencing is proposed where stage I is very fine and the value of stage IV remains unclear (functional rather than stylistic grouping?).

Sites belonging to the Blicquian culture are located in Central Belgium (Fig. 1). Two settlement areas can be identified: one in the West, in western Hainaut, and the other in the East, in Hesbaye. The absence of sites between these two centres, some 100 km apart, may well reflect a historical reality. To date, surveys have only produced isolated discoveries between these two areas (JADIN *et al.*, 2003; VAN ASSCHE, 2008).

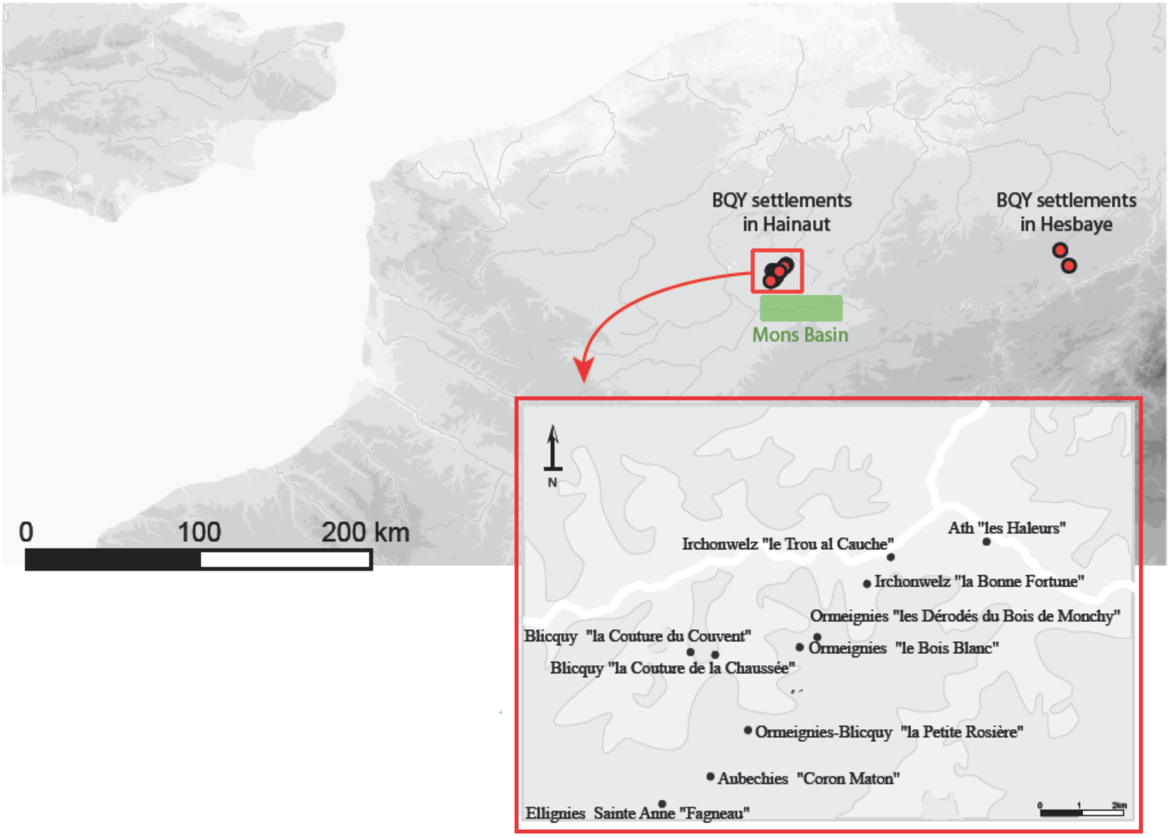

Fig. 1 – Map of the Blicquian sites. Zoom on the Blicquian (BQY) sites of Hainaut. In green: localisation of the Mons Basin which delivered the main flint outcrops exploited by the BQY populations.

Localisation	Abbr.	Discoverer	Excavation years	Organisations	Surface area	Number of features	Number of houses	Chrono-logical stage
Irchonwelz 'la Bonne Fortune', Hainaut	IBF	M. Daubechies	1978, 1980, 1983	CNRS, URA 12; CTRA Blicquy-Aubechies	1800 m2	16	3	Early
Irchonwelz 'le Trou al Cauche', Hainaut	ITC	M. Daubechies	1991	CTRA Blicquy-Aubechies; Ministère de la région wallonne ; Service de Préhistoire Université de Liège	1500 m2	10	1 + 0.5?	Early
Ellignies-Sainte-Anne 'Fagneau', Hainaut	ESAF	L. Demarez	1969, 1970, 1976	CTRA Blicquy-Aubechies; Service National des Fouilles de Belgique	?	10	?	Middle
Aubechies 'Coron Maton', Hainaut	ACM	L. Demarez	1980, 1988, 1999	CNRS, URA 12; CTRA Blicquy-Aubechies	1430 m2	23	1 or 2?	Late
Ormeignies 'la Petite Rosière', Hainaut	OPR	L. Demarez	1981	CNRS, URA 12; CTRA Blicquy-Aubechies	210 m2	3	0.5?	?

Fig. 2 – Description of the studied BQY site characteristics.

Nine of the twelve Blicquian sites are located in western Hainaut, to the south-west of Ath, in the area where the River Dendre originates (Fig. 1). This settlement zone is extremely localised as these sites are all concentrated within an area of 27 km^2 (CONSTANTIN & BURNEZ-LANOTTE, 2008; CONSTANTIN *et al.*, 2009). However, a tenth site has recently been discovered near the eastern Dendre (DERAMAIX *et al.*, 2016), extending the Blicquian occupation area by a few kilometres eastwards in Hainaut. This site, called Ath 'Les Haleurs', is currently under excavation and has not been included in the present study.

Generally, only small areas have been excavated so it is difficult to assess the spatial organisation within the villages. However, most of the features correspond to lateral pits and allow for comparisons between sites. Lateral pits and postholes are often the only elements that materialise the location of houses. The lateral pits are dug in the immediate vicinity of the longest sides of these houses, to the north and south.

In spite of the limited extent of the excavations, these Blicquian features delivered a plentiful lithic assemblage representing more than 90,000 pieces. We selected a sample for this present study consisting of about 45,000 pieces. Here, we will focus on the methodological tools that allowed us to deduce that a form of specialist blade production operated in Hainaut. With this perspective, four sites were then studied exhaustively (Fig. 2): Irchonwelz 'la Bonne Fortune', Ellignies-Sainte-Anne 'Fagneau', Aubechies 'Coron Maton' and Ormeignies 'la Petite Rosière'. In Irchonwelz 'le Trou al Cauche', the richest lateral pit was taken into account for comparisons.

2. Raw material procurement

The closest outcrops to the Blicquian sites are located about 15-20 km away, in the Mons Basin (Fig. 1), which was expected to contain a lot of outcrops. Unfortunately, the issue of flint provenancing is much more difficult to tackle given that there is currently no systematic reference collection. Given the fact that 22 Cretaceous formations are represented (ROBASZYNSKI *et al.*, 2001), numerous possibilities exist. Traditionally, in the literature, four types of flint are mentioned: Obourg flint, Ghlin flint, Turonian flint and Spiennes flint (CAHEN & VAN BERG, 1979; CAHEN *et al.*, 1986; HUBERT, 1982; ALLARD, 2005; ALLARD *et al.*, 2010). The Danubian populations did not use the latter. The BQY industry of Hainaut shows a preference for the Ghlin flint, which represents between 60 and 80 % (CAHEN & VAN BERG, 1979; CONSTANTIN, 1985; DENIS, 2014, 2017). Therefore, even if the outcrops are not accurately located, we can rationally assume that the Ghlin flint was gathered in the Mons Basin, probably in the area of Baudour (COLLIN, 2016; LEBLOIS, 2000). The different types of cortex show that the BQY population collected the Ghlin flint both from primary and secondary positions.

3. The organisation of production: a dual structure

The study of production organisation resulted in the identification of two kinds of production, with different levels of technical expertise (Fig. 3). On the one hand, some production can be called simple because it only required a low to very low level of savoir-faire. On the other hand, blade production requires a higher level of skill. The Ghlin flint is largely used for producing blades whereas simple production is more frequent for the other types of raw material.

3.1. Simple production

Three types of simple production were identified: flake production, production of facetted tools and production of *pseudo-frites* on flake edges. The production of flakes and facetted tools are closely related since they are frequently combined. They lead to the production of denticulated, retouched flakes and facetted tools. However, the production of *pseudo-frites* on flake edges has not been identified up until now in VSG contexts. It consists of knapping varieties of large burin spalls after the rapid shaping of a sort of crest on the edge of a large flake (Fig. 3). This production uses special knowledge probably inherited from the LBK, where *frite* production is well attested (CAHEN, 1984; CAHEN *et al.*, 1986; ALLARD, 2005). Nevertheless, the *chaîne opératoire* implemented for these three types of production is simple. A hard hammer stone is used to create the debitage. Frequent marks of technical clumsiness are present, such as hinged flake scars, or the distribution of impact points related to a poor adjustment of the knappers' gestures, reflecting a low to very low level of savoir-faire. In each household, the whole *chaîne opératoire* can be identified, suggesting that the production of flakes and facetted tools occurs primarily in a domestic context. The situation is unclear for the production of *pseudo-frites* on flake edges.

3.2. Blade production

Blade production necessarily involved a significantly higher level of expertise than simple flake production due to the implementation of a

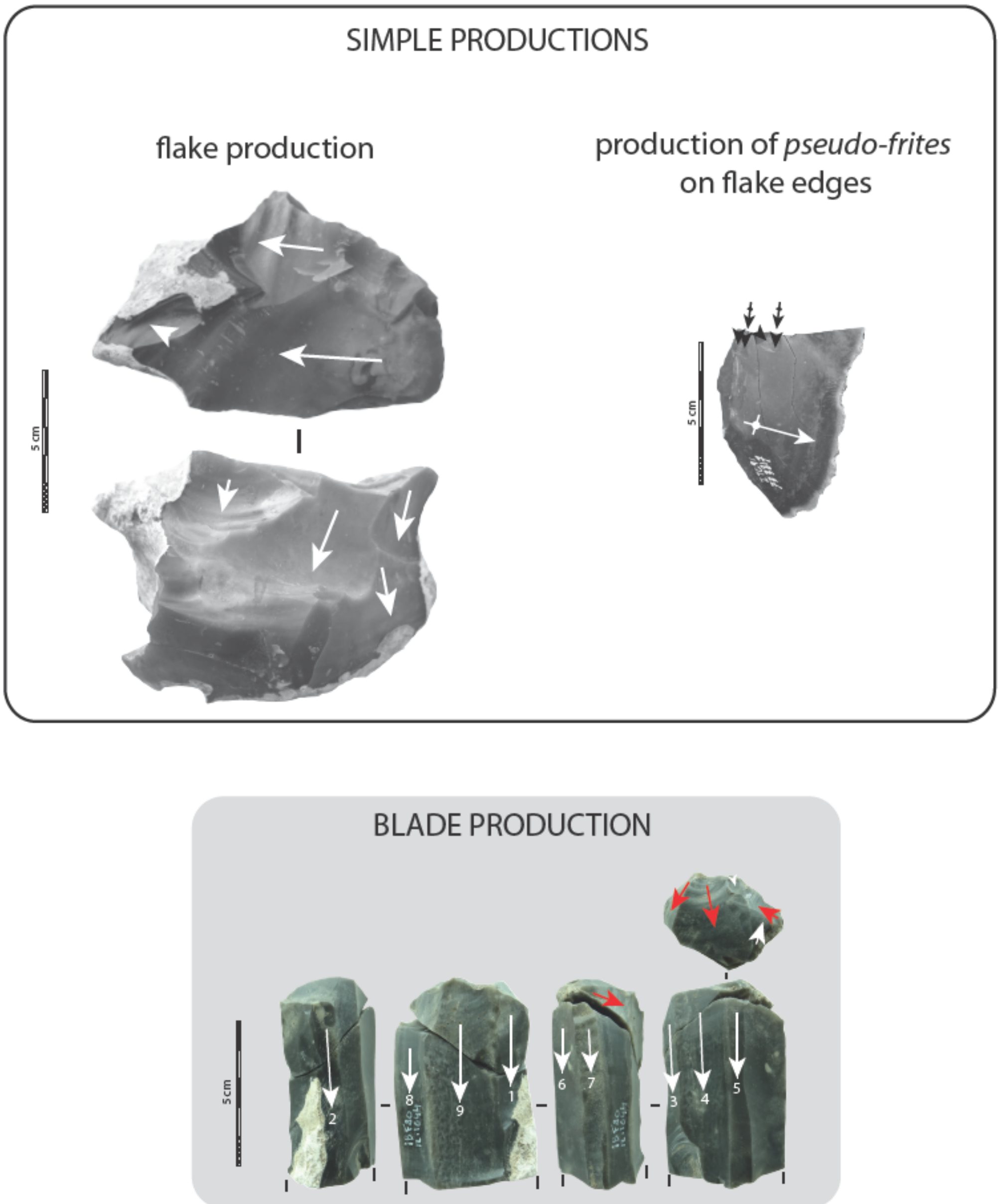

Fig. 3 – Cores representing the two kinds of productions, opposed by the level of expertise: simple products and blades. Examples of simple productions: flake core from Vaux-et-Borset; core from Irchonwelz 'le Trou al Cauche' linked to the production of *pseudo-frites* on flake edge. Blade core: Irchonwelz 'la Bonne Fortune'.

predetermined *chaîne opératoire*. We will focus here on the production using Ghlin flint, which is largely dominant in Hainaut.

The shaping phase of blade production involves cresting. Blades are obtained by indirect percussion. The striking platforms are facetted and the debitage is often rotating, cores have peripheral blade surfaces. This production generally aims to obtain blades about 10 cm long, with a width of 18-20 mm and a thickness of 5-6 mm.

In addition, production is geared towards trapezoidal blades with symmetrical sections, as evidenced by the high number of blades with three facets and an operating code 212'. This code corresponds to the order in which the previous blades were detached. So, the interpretation of this code gives the organisation of the debitage. Such products can be repeatedly obtained by initialising and maintaining specific debitage arrangements, which knappers need to know and implement successfully (Pelegrin, pers. com.). Thus, we can establish that the standard skill level of Ghlin blade knappers was very good.

This duality of production reflects the existence of two groups of knappers who do not have the same knowledge and savoir-faire, as has already been demonstrated by A. Augereau in VSG contexts (AUGEREAU, 2004).

4. BLADE PRODUCTION: SHARING SKILLS BETWEEN SEVERAL VILLAGES?

We will focus our analysis on the blade production using Ghlin flint, which is most common on the Blicquian sites of the Hainaut.

4.1. Techno-economic diagrams

The methodological tool used here is the techno-economic diagram (PERLÈS, 1990). It enables us to visualise the quantitative representation of the different stages of the blade production *chaîne opératoire* carried out on the sites or within the different households when the excavated corpus is suitable.

In keeping with the observations made on the *chaîne opératoire,* we chose to use a diagram constructed on eight categories of artefacts (Fig. 4).

The first techno-economic class concerns the primary flakes from shaping the core. Their identification is complex where these industries are based on a dual organisation (simple production/blade production). They are usually obtained by hard hammer stone percussion which shapes out the core, giving it an ideal morphology for cresting.

This last step is the second category of our diagrams that includes preparation flakes from cresting.

The crested blades themselves are classified as a third category. This helps to identify a possible segmentation of the *chaîne opératoire* at the end of shaping the cores.

The fourth category comprises all the pieces attributed to the maintenance of all types of blade debitage. These may include the maintenance of the striking platform or core convexities, the correction of accidents, regularisation of the flanks or ridges.

The fifth category represents the intended blanks, the blades.

The sixth techno-economic class consists of flakes that appear to be attributable to blade debitage according to the evidence of indirect percussion or the reading of diacritical schemas. However, we were not able to assign them to a more specific stage of the *chaîne opératoire*.

The seventh category consists of small flakes produced by indirect percussion, the small retouch flakes attributable to blade production by interpreting the diacritical schemas. These consist mainly of blade tool spalls, mainly burin spalls.

The eighth category consists of blade cores. The latter are, with very few exceptions, reused for low-skill production, particularly flake production. Also, flakes from simple blade core production are also included in this category.

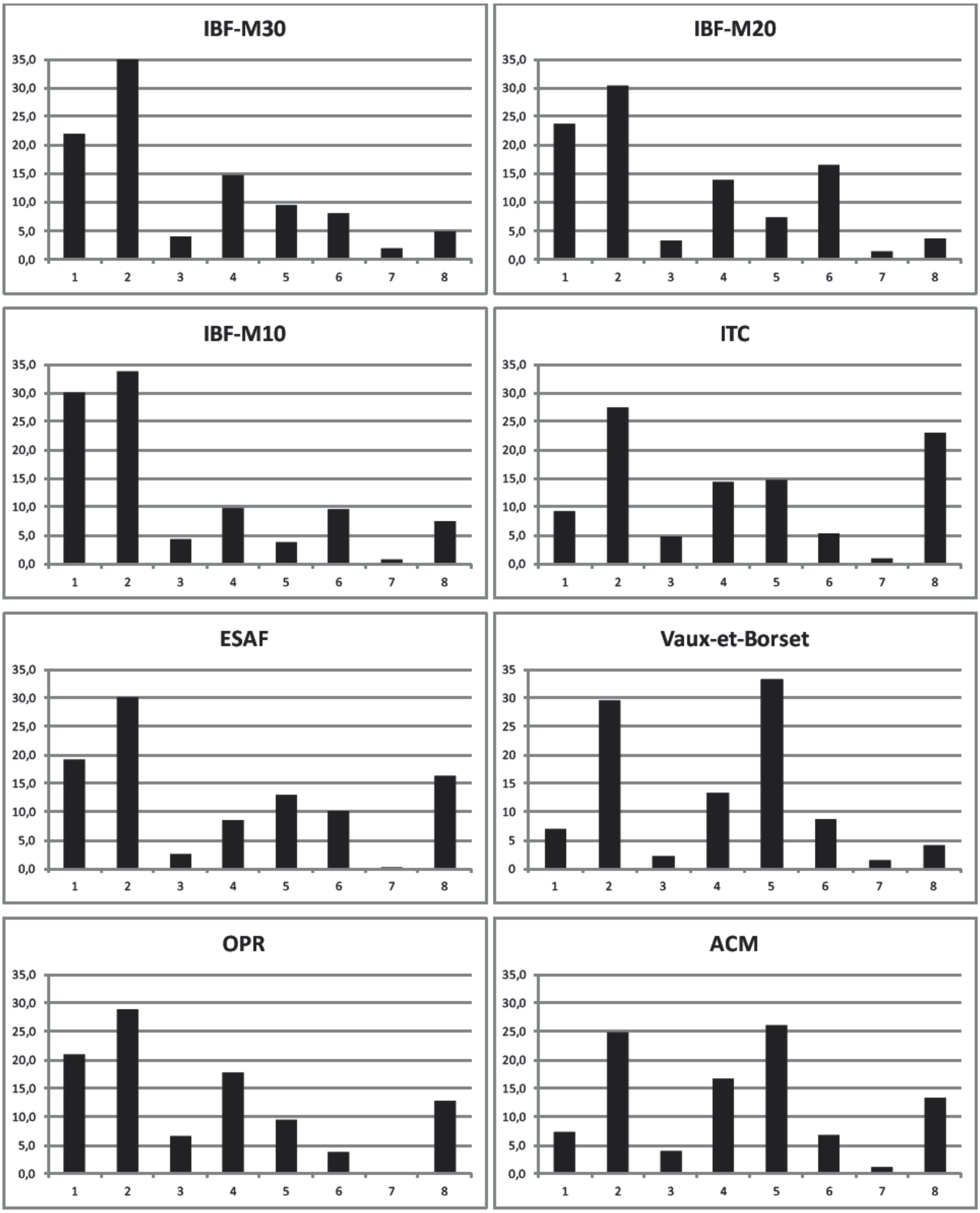

Fig. 4 – Techno-economic diagrams of the blade production in Ghlin flint for the different sites studied, in % of weight.

A general reading of these techno-economic schemas leads to the identification of all the stages of the *chaîne opératoire* within each site or household (Fig. 4). It can therefore be said that the debitage takes place within each domestic unit. But does that mean that each household has a blade knapper and autonomous lithic tool production? Various strands of evidence converge to indicate the existence of producers at the village or even supra-village scale.

4.2. Blade production and levels of expertise

The characteristics of the blades and the *chaîne opératoire* of Ghlin flint blade production show that knappers generally have a good level of skill (Fig. 5). The evaluation of the regularity of the blades led us to establish a four-tiered classification, ranging from 0 –very regular blades- to 3 –very irregular blades - (Fig. 5). Between 50 and 60 percent of the blades are regular blades (level 1). This degree of regularity corresponds to the level of average (or standard) savoir-faire observed on the Blicquian sites. The search for trapezoidal blades with code 212′ involves the implementation of particular debitage arrangements (BINDER & GASSIN, 1988; BINDER, 1991; ASTRUC *et al.*, 2007; Fig. 6). These require not only knowledge but also the necessary savoir-faire to initiate and maintain them. It is therefore possible to establish that the standard skill of Ghlin flint knappers was very good. Therefore, it is possible to isolate all the pieces that deviate from this level of competence.

4.2.1. From apprentice knappers...

During the study of the Ghlin flint blade cores, we had the opportunity to identify three cores showing the work of young knappers or apprentices. A preform discovered in Feature 5 of Ellignies-Sainte-Anne could not lead to the creation of blades due to poor control of the convex surfaces. In Feature 21 of Irchonwelz 'la Bonne Fortune', a preformed tablet was

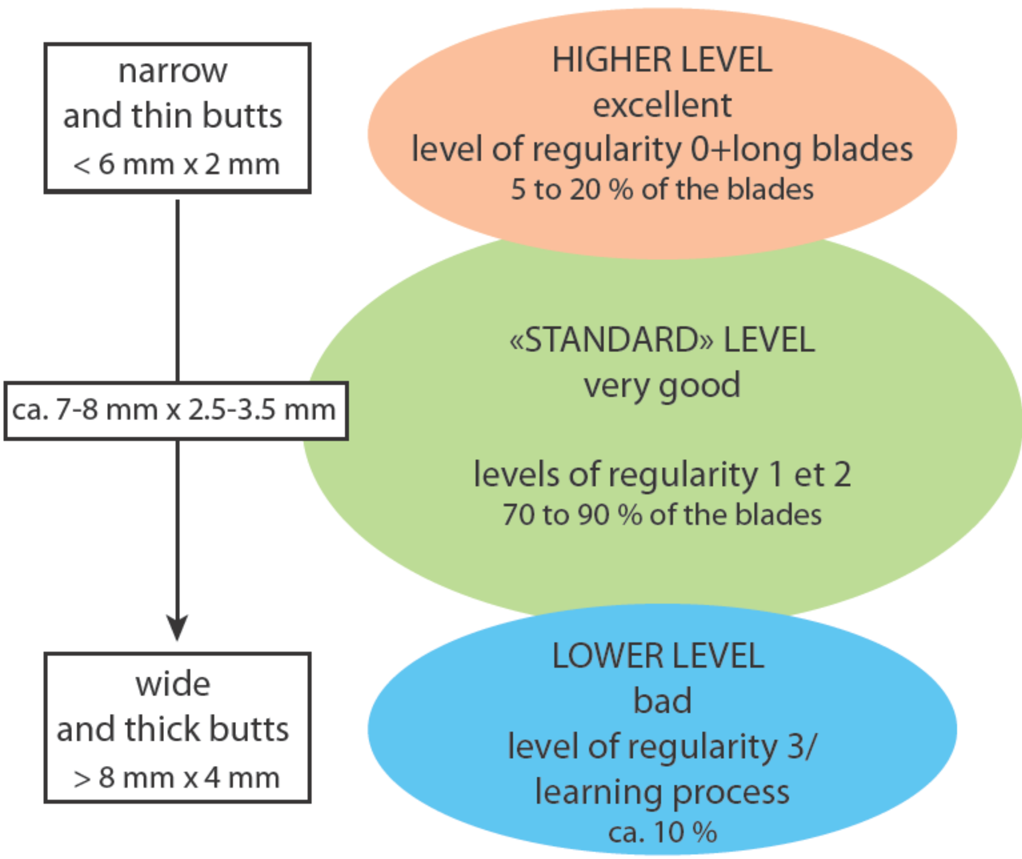

Fig. 5 – Distinction of 3 levels of skill in the blade production.

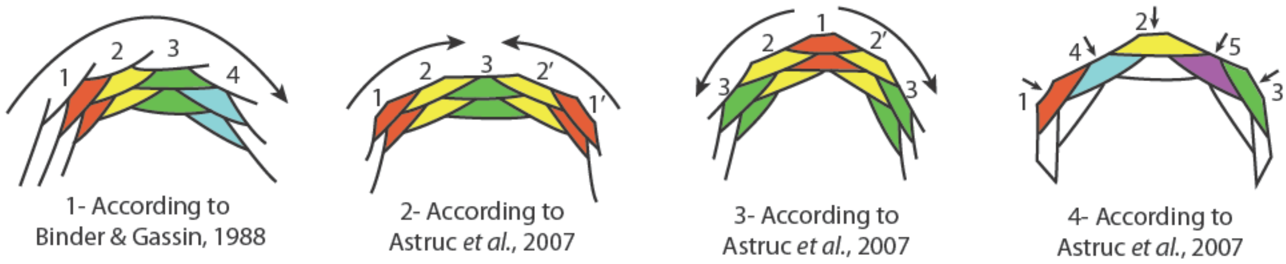

Fig. 6 – Particular arrangements of the debitage which led to obtain trapezoidal blades with 212′ code. After Jacques Pelegrin's figure (ASTRUC *et al.*, 2007) built after a long experience of knapping tests and observations of archaeological material.

knapped using a short debitage sequence that was stopped by a knapping accident (Fig. 7). This piece also shows the work of a knapper in the process of acquiring the skills needed to produce blades. Finally, in Feature 9 of Irchonwelz 'la Bonne Fortune', an economically exhausted core (no further desired blank can be obtained) was probably then reworked by a young knapper.

Thus, some artefacts attest to the presence of young or apprentice knappers involved in the process of acquiring the necessary knowledge and savoir-faire for blade production. No blade

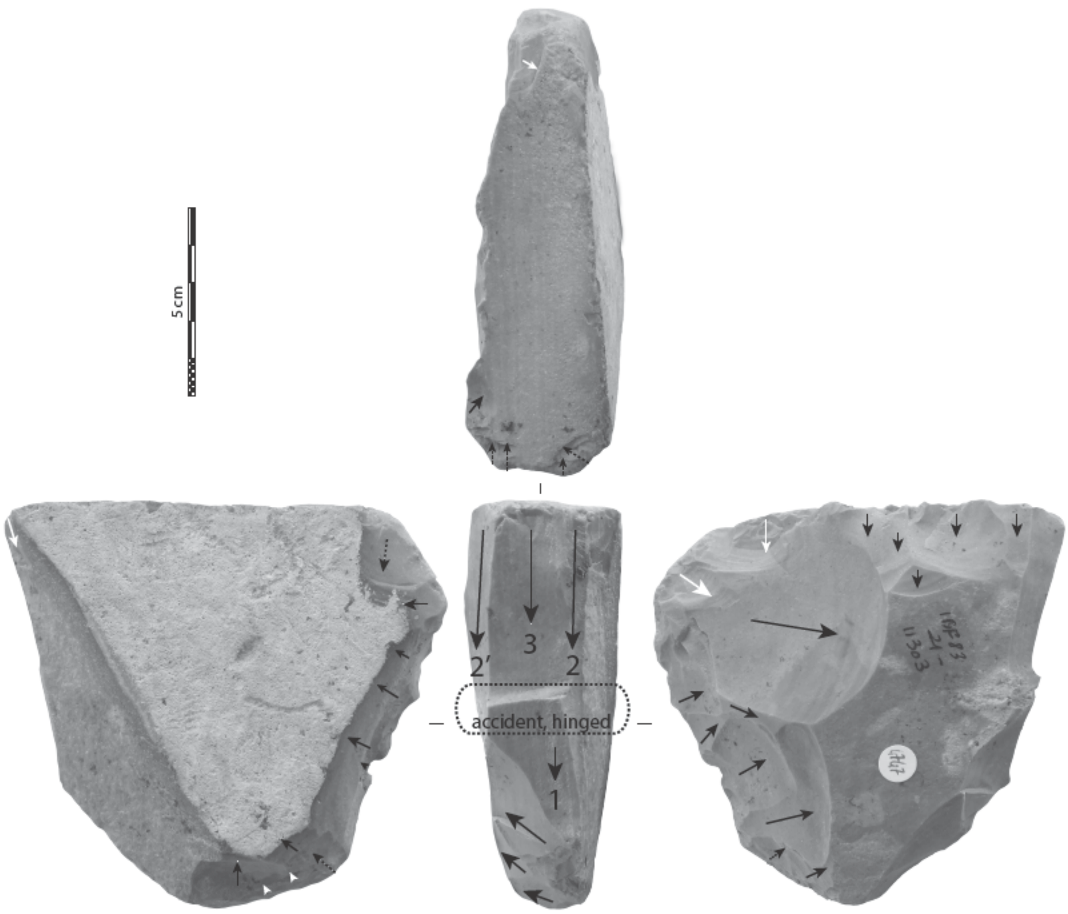

Fig. 7 – Ghlin flint tablet knapped by an apprentice, Irchonwelz 'la Bonne Fortune', Feature 21.

was actually obtained from the debitage. On the other hand, the very irregular blades and even some irregular blades (ranks 2 and 3) could reflect the presence of knappers able to carry out blade production but with a lower level of savoir-faire than the standard level (Fig. 5).

We will focus here on the very irregular blades which diverge the most from the average level of savoir-faire. The butt sizes of these blades tend to be larger than those of the blades corresponding to the standard level of expertise (Fig. 5). This is a good indicator of a low level of skill. With the exception of the site of Irchonwelz 'la Bonne Fortune', these very irregular blades seem to play little or no role in the toolkit. Thus, some of these very irregular pieces do not seem to have the same economic value as the rest of the production.

Consequently, in addition to the evidence of young people involved in the process of acquiring the necessary savoir-faire to produce blades, these very irregular blades could correspond to a slightly higher level of skill, but nonetheless lower than that for standard production.

In contrast to this evidence of apprentices, some blades display 'exceptional' characteristics that set them apart from average skill.

4.2.2 ...to the best knappers

The artefacts showing superior expertise can be divided into two groups: on the one hand, extremely regular blades and, on the other, very long blades.

Some blades exhibit an above average level of skill on account of their marked regularity. They are characterised by the parallelism of their edges and the regularity of their dorsal ridges (Fig. 8). Other parameters are often emphasised, such as straightness, the regularity of their profile, their thinness and the restricted dimensions of their butts. Cores corresponding to this quality of debitage were discovered at Ellignies-Sainte-Anne. The most regular artefacts from Hubert's excavation present extremely regular scars. On the final removals, sharp ripples are visible, particularly on the bulb of percussion on the blade. Such characteristics suggest the use of pressure flaking, which has already been mentioned in publications for the Blicquy group (CAHEN & VAN BERG, 1979; CONSTANTIN, 1985; CAHEN *et al.*, 1986; JADIN *et al.*, 2003). However, the criteria described above are not all simultaneously present. Moreover, with rare exceptions, these blades have a mesial bulge on their ventral surface or 'belly', which is typical of indirect percussion (Pelegrin, in preparation). A single artefact, discovered in Feature 9 of Irchonwelz 'la Bonne Fortune', presents all the characteristics of pressure flaking: small butt, thinness, straight edges and parallel and regular dorsal ridges, ripples on the bulb of percussion which is high and short. However, this is the only artefact for which pressure flaking could be identified. It is therefore reasonable to rely on the rates of recovery of the two techniques, particularly in the case of the use of indirect percussion by knappers with an extremely good level of savoir-faire.

These very regular artefacts therefore correspond to the most competent elements of Ghlin's flint blade debitage. The knappers possess the same knowledge but optimal savoir-faire. Long blades also show the existence of special expertise.

These long blades exceed 14 cm and reach a length of up to 20 cm, which is about twice as long as for standard blade production. However, 'the difficulty of producing large regular pieces grows exponentially with their size' (PELEGRIN, 2002, p. 142). Consequently, these artefacts necessarily involve a greater degree of savoir-faire than for standard blade production, all the more so as the shaping of large nodules involves specific knowledge and savoir-faire. However, the elements from this *chaîne opératoire* do not have present enough specific attributes to be identified and located, with the exception of a potentially large core from Irchonwelz 'la Bonne Fortune' (House 30). It is therefore difficult to locate the precise place of production of these large blades, especially since they are only rarely present. Nevertheless, it seems obvious that these pieces were not produced in a domestic context since they were not discovered at all of the sites and within all the housing units. They have been recovered from:

- House 30 of Irchonwelz 'la Bonne Fortune'. However, these are only crested blades with the longest 16 cm. It could therefore be suggested that no blade longer than 16 cm had been produced.
- On the other hand, the long blade discovered in Feature 5 of Ellignies-Sainte-Anne measures 19.5 cm, which is considerably larger than IBF. This very curved blade presents four facets and a small butt (7 x 2 mm) and was left intact and unretouched.

Other long blades have been discovered on other BQY sites. These include an artefact discovered in Vaux-et-Borset (Hesbaye). This trapezoidal blade is shorter and wider than the Ellignies-Sainte-Anne blade. It measures 150 x 27 x 8 mm and had been used. Long blades are also present at Blicquy 'la Couture de la Chaussée'. We had the opportunity to examine the one preserved at the Domus Romana (Aubechies). It is a blade with a triangular section measuring 187 x 22 x 7 mm and a small butt measuring 5 x 1 mm. This blade, like that of Ellignies-Sainte-Anne, has survived intact. The publication of the site of Blicquy 'la Couture de la Chaussée' shows the existence of a second long blade. This latter is a crested blade measuring 152 x 19 x 12 mm (CAHEN & VAN BERG, 1979, p. 22). As for the other sites not studied exhaustively here, long blades also appear to be present at Ormeignies 'le Bois Blanc' (CONSTANTIN *et al.*, 1982). They are all from Feature 2, unretouched and measure 155 x 29 x 5 mm, 146 x 23 x 5 mm

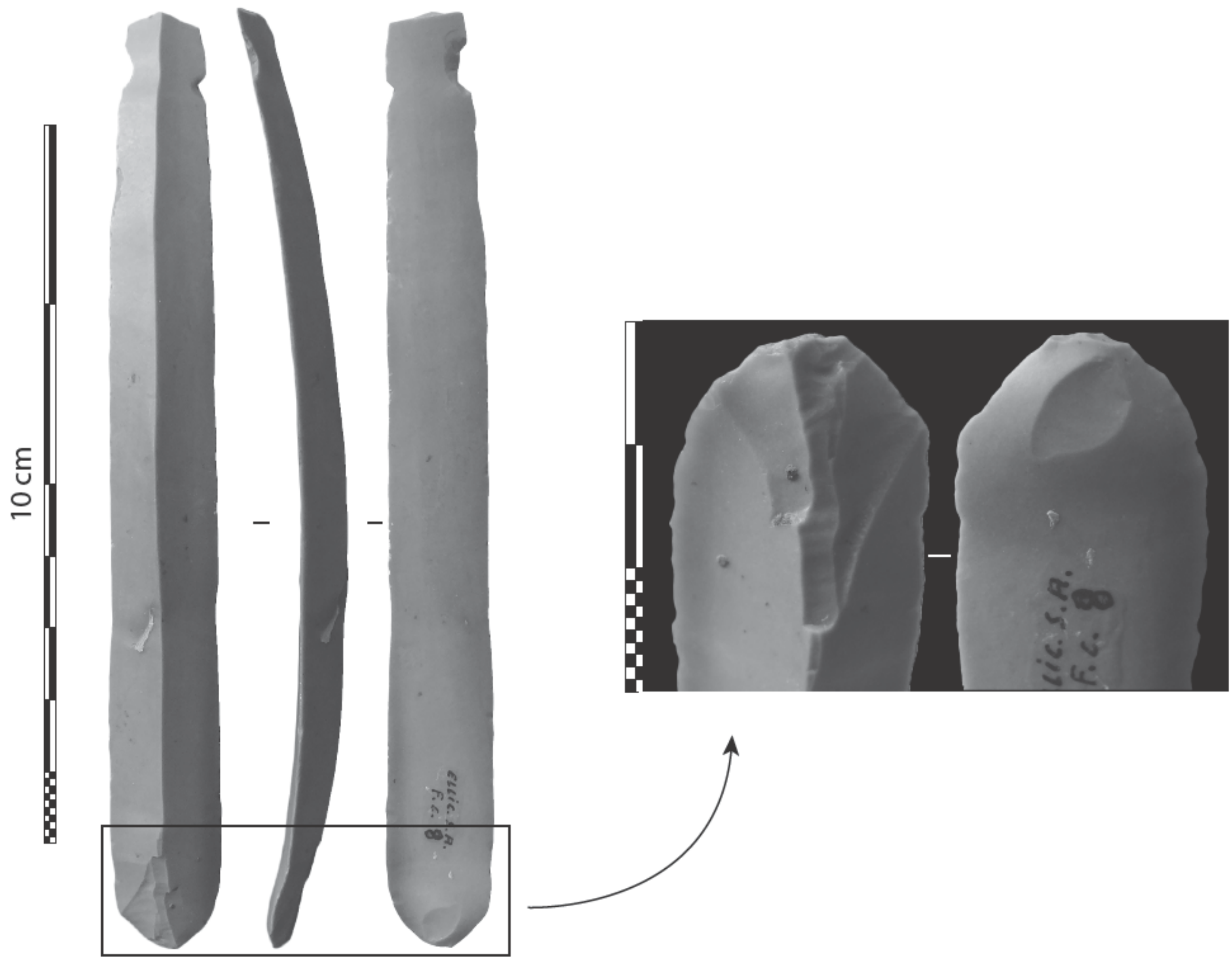

Fig. 8 – Very regular blade in Ghlin flint discovered in Ellignies-Sainte-Anne excavated by François Hubert (SNF, in 1970-1971 and 1980), conserved in the Archaeological Department, SPW.

and 141 x 18 x 6 mm. It is specified in the bibliography that they were 'discovered grouped in packages'. They can thus be considered as a hoard (CONSTANTIN *et al.*, 1982, p. 29).

Taken together, these long blades reflect the presence of knappers with an excellent level of skill. They were only identified in House 30 of Irchonwelz 'la Bonne Fortune', Feature 5 of Ellignies-Sainte-Anne, the Blicquy eponymous site, Vaux-et-Borset and Ormeignies 'le Bois Blanc'. They are also rare and in the minority in these assemblages. This production of long blades in Ghlin flint therefore appears quantitatively marginal and this may result from constraints linked to the quality of the raw material. The outcrops of Ghlin flint perhaps only offered a few large tablets capable of producing long blades. This production is not identified at all sites and the contexts of discovery are sometimes uncommon (Ormeignies 'le Bois Blanc'). Although it is difficult to prove the location of their production, it is obvious that this production was not carried out on a domestic scale. In addition, the savoir-faire required to produce these large blades was much higher than for standard blade production. This long blade production involved in particular the perfect control of the shaping of large volumes.

The examination of the level of expertise of Ghlin flint blade producers shows on the one hand the existence of apprentices, young knappers and knappers with a standard level of skill. The quality of Ghlin flint blade debitage makes it possible to assert that the savoir-faire involved was very good. But this is nonetheless distinguished from the blade debitage which shows a very high degree of expertise. This is revealed in two ways; on the one hand, these are extremely regular blades, and on the other, by the presence of rare long blades.

In each domestic unit, these three levels of skill are identified. This immediately rules out the presence of a single knapper within the domestic unit. Since the pits seem to have been filled rapidly (ALLARD *et al.*, 2013), at least in LBK contexts, these three levels would not be indicative of the technical progress of the knappers, but of three separate individuals.

4.3. Annual production output

However, an evaluation of the annual production output runs counter to the hypothesis of the coexistence of three knappers in each household.

To establish a hypothetical annual output, the data are analysed per house for Irchonwelz 'la Bonne Fortune'. The sites of Ellignies-Sainte-Anne and Aubechies contained several pits which (certainly) came from different domestic units. However, in the absence of a clear spatial organisation at these sites, we took into account all of the features, which necessarily resulted in inflating the annual production output. On the other hand, at Ormeignies 'la Petite Rosière', two pits belonged to the same house. We multiplied the number of blades by two to estimate the production of an entire building. Similarly, we multiplied the number of blades by four in Irchonwelz 'le Trou al Cauche' since only one pit was studied. To model this annual output, we have used the recent results obtained at the LBK sites of the Aisne valley which suggest a rapid filling of the pits within three to five years (ALLARD *et al.*, 2013). Experiments suggest that the debitage from a block leads to the production of 20 to 30 blades (Pelegrin, pers. comm.). Thus, annual output is very low (Fig. 9). Less than six blocks would have been knapped in a given year per household unit, or a maximum of two blocks per knapper (based on the model of three individuals per farmstead). This number could just be enough to maintain the skill level of an excellent knapper. On the other

Ghlin flint	no. blades	annual output	no. blocks/year
IBF10	32	6 to 11	<1
IBF20+9	368	74 to 123	2 to 6
IBF30	244	49 to 81	2 to 4
ESAF	258	52 to 86	2 to 4
ESAFHUb	207	41 to 69	1 to 3
ACM	327	65 to 109	2 to 5
ITC73	91	72 to 120	2 to 6
OPR	27	10 to 18	1
VCM98	96	128 to 76	3 to 6

Fig. 9 – Evaluation of annual output of Ghlin blades in the settlements studied.

hand, this level of output is clearly insufficient to optimise the skills of a young knapper in the process of acquiring knowledge. This estimate of annual production output does not suggest that production was in a 'domestic' context.

4.4. The techno-economic diagrams: quantitative variations of certain stages of the *chaîne opératoire*

We have already mentioned that the techno-economic diagrams for the blade production of the Ghlin flint show that production took place within the villages, but we have not yet considered the quantitative variations (Fig. 10). Three techno-economic classes can be identified on the basis of considerable variations between sites. These are primary flakes from the beginning of shaping out, blades and cores (Fig. 10 and Fig. 11).

All Irchonwelz 'la Bonne Fortune' farmsteads show an over-representation of primary flakes and a distinct shortage of blades. The site of Ormeignies 'la Petite Rosière' follows the same pattern. Ellignies-Sainte-Anne also has a high proportion of primary flakes but a greater blade proportion. On the other hand, blades are more abundant at Aubechies than elsewhere, even when primary flakes are poorly represented. At Irchonwelz 'le Trou al Cauche' and at the Hubert excavation at Ellignies-Sainte-Anne, cores appear to be more heavily represented than at the other sites.

Blades are consistently under-represented in household units with a high level of primary flakes (Fig. 11 and Fig. 12). It is thus tempting to see the concomitant transport of preforms and blades by knappers from these sites.

By comparison, the Aubechies site has a high percentage of blades. The techno-economic diagram of Vaux-et-Borset shows strong similarities with that of Aubechies. In Vaux-et-Borset, Ghlin flint is clearly exogenous. It was brought by knappers from Hainaut, in the form of blocks and preforms, as well as blades (DENIS, 2014).

This differential representation of the different techno-economic classes could signify a certain dependency amongst the sites for the production of blades, which could result from the knapper moving from one farmstead to another, and even from one village to another (Fig. 13).

4.5. Concentration of waste production from apprentices and most skilled knappers

Lastly, we will develop a final argument. The transmission of knowledge of this blade production obviously involves the presence of apprentices. If there are very irregular blades in each household, then these are probably an indication of inexperienced knappers. Furthermore, we pointed out earlier the

% WEIGHT	1	2	3	4	5	6	7	8	TOTAL
IBF10	30	34	4	10	4	10	1	7	100
IBF20+9	24	30	3	14	7	16	1	4	100
IBF30	22	35	4	15	9	8	2	5	100
OPR	21	29	7	18	9	4	0	13	100
ESAF	19	30	3	9	13	10	0	16	100
ITC	9	27	5	14	15	5	1	23	100
ESAFHub	8	30	5	14	14	5	0	24	100
ACM	7	25	4	17	26	7	1	13	100
Vaux-et-Borset	7	30	2	13	33	9	2	4	100

BEGINNING OF SHAPING OUT — BLADES — CORES

Fig. 10 – Quantitative variations in the techno-economic diagrams of the Ghlin flint blade production, in % of weight.

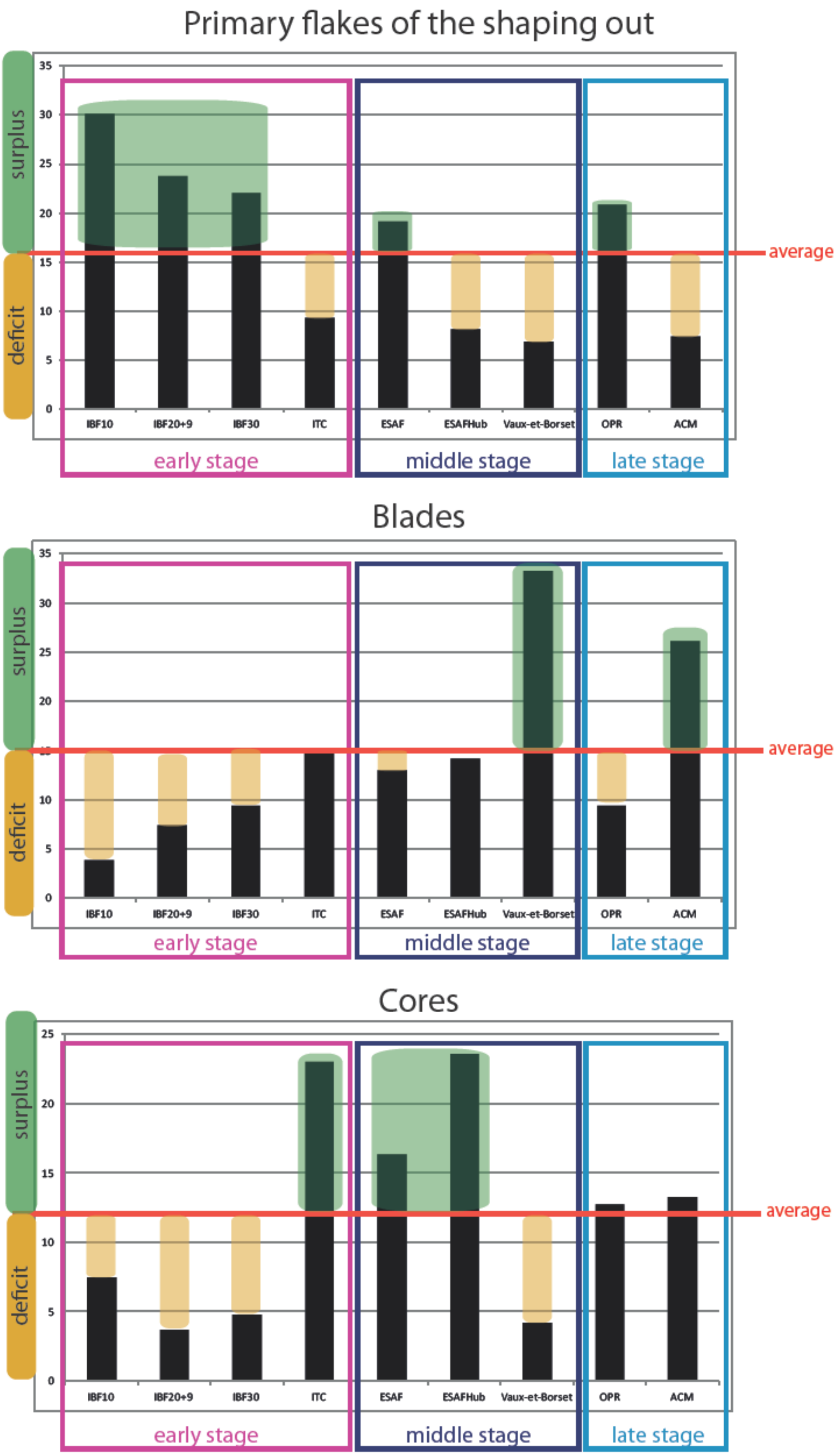

Fig. 11 – Focus on the quantitative variations of three stages of the *chaîne opératoire* of Ghlin flint blade production: the first step of the shaping out, the blades and the cores (in % of weight). Classified by chronological stages, the distinction of the surplus and the deficit shows a kind of balance between sites.

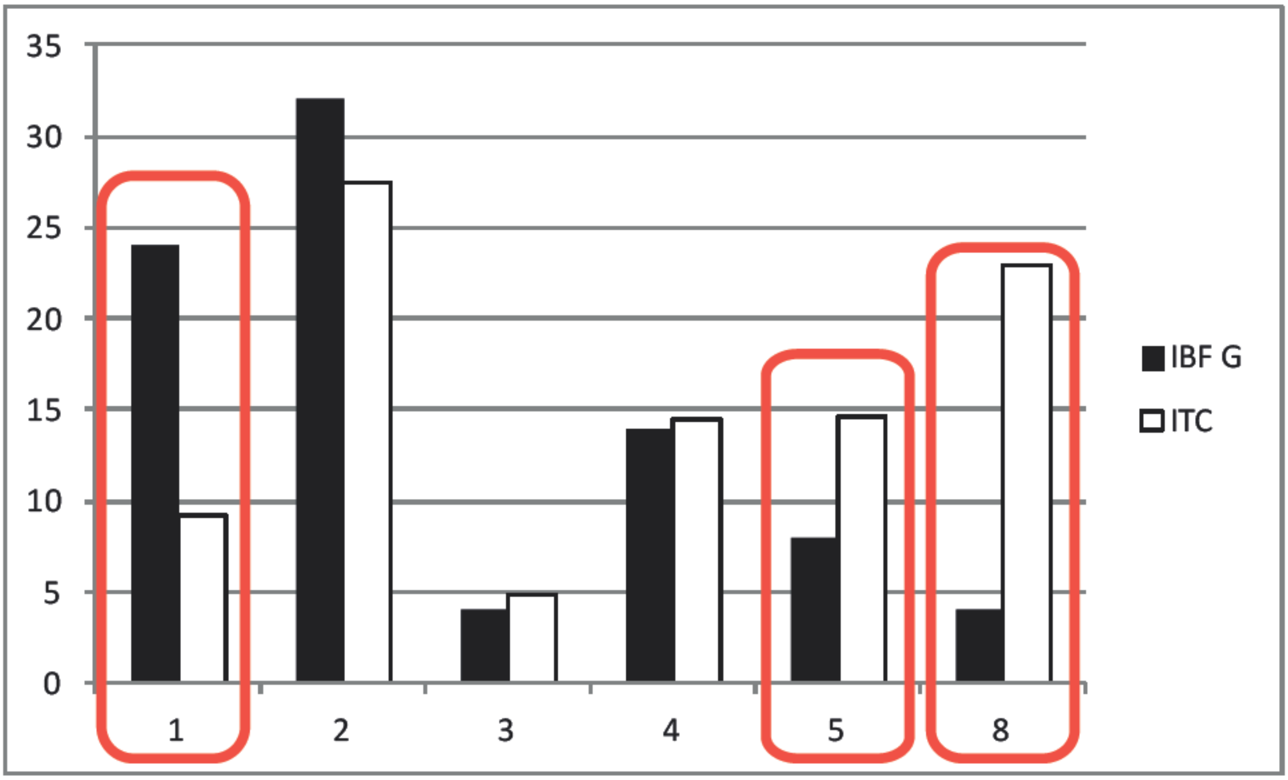

Fig. 12 – Comparisons between the techno-economic diagrams of Irchonwelz 'la Bonne Fortune' and 'le Trou al Cauche': the surplus and the deficit show a kind of balance between the two sites.

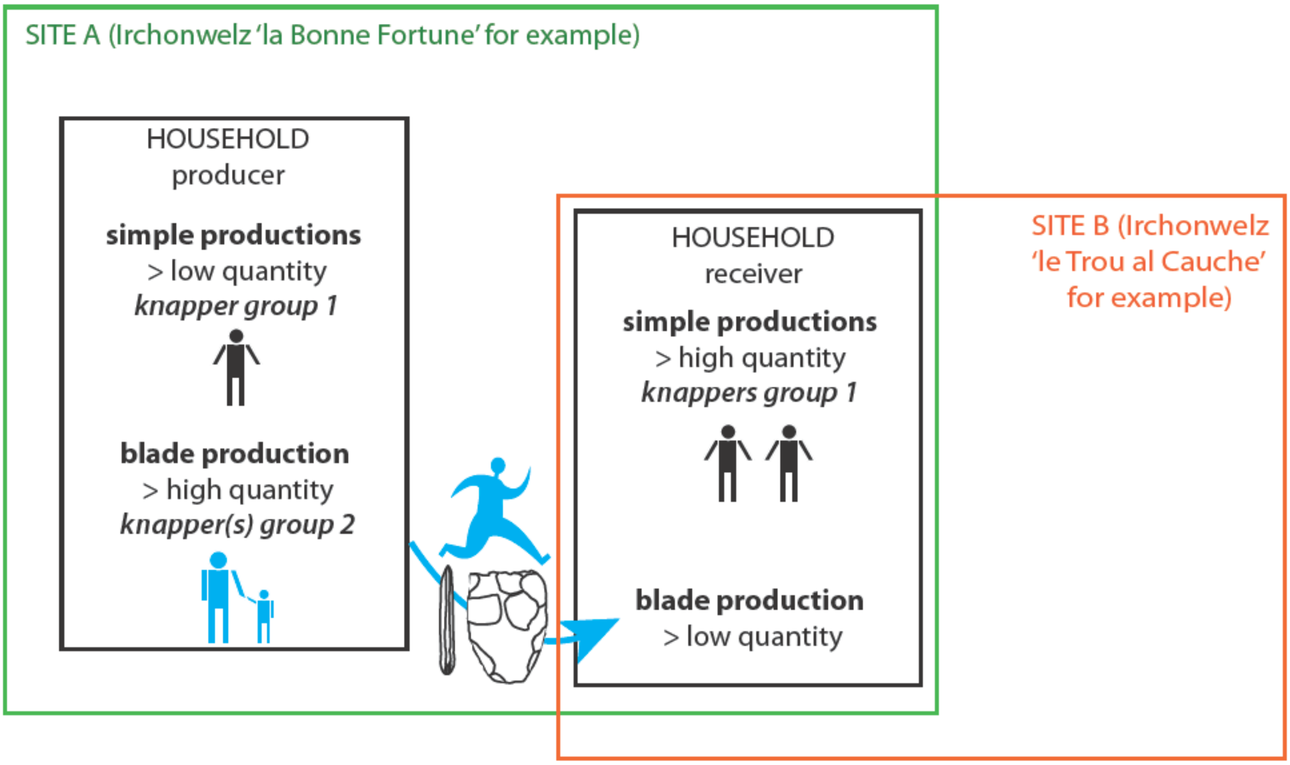

Fig. 13 – Synthetic schema of the production organisation.

existence of preforms and a core that attest to debitage created by young people in the process of acquiring the necessary skills to produce blades. These traces of learning are undoubtedly fleeting. But they are probably difficult to detect, especially within this dual production structure. The three pieces that potentially attest to such apprenticeship work come from Features 9 and 21 of Irchonwelz 'la Bonne Fortune' and Feature 5 of Ellignies-Sainte-Anne, namely from features where a certain overrepresentation of primary flakes from the shaping out phase was identified. On the other hand, very regular blades have been found in almost all the domestic units, but they are more frequent in Irchonwelz 'la Bonne Fortune'. The most regular cores were discovered at Ellignies-Sainte-Anne (Hubert excavation and Feature 5) and in House 30 at Irchonwelz 'la Bonne Fortune'. A certain concordance emerges from these different parameters, where Ellignies-Sainte-Anne and Irchonwelz 'la Bonne Fortune' contain a surplus of primary flakes from shaping out, very regular blades and evidence of training. Finally, the long blades that demonstrate the work of excellent knappers have been identified in House 30 of Irchonwelz 'la Bonne Fortune' and in the Ellignies-Sainte-Anne Feature 5. The production from both the best knappers and apprentices therefore appears to be concentrated in the same features, which also present a certain overrepresentation of waste products.

5. Conclusion

To summarise, it seems that the evidence converges to imply that the domestic Blicquian unit was not autonomous when producing blades. There was probably no specific blade knapper in each household. It is possible that knappers moved from one farmstead to another, and especially from one site to another, to produce blades (Fig. 13). The example of the site of Aubechies seems rather convincing for this latter perspective. There would thus have been a form of specialised inter-community production, with specialisation being characterised here as a small group of knappers who held skills not accessible to all and whose blade production was destined for redistribution to a larger community (Roux & Pelegrin, 1989; Perlès, 2001). The concentration of waste debitage and a small proportion of blades at Irchonwelz 'la Bonne Fortune' suggest that preforms and blades were removed from the site. This example is reminiscent of the situation in Langweiler 8 in the Merzbach Valley (Zimmermann, 1995; Lüning, 1998) where Langweiler 8 was described as a central site.

The interpretation of these techno-economic schemas makes it possible to determine whether the debitage occurred *in situ* or not. Other criteria have to be combined with these schemas in order to enhance our understanding of the socio-economic organisation of production. Indeed, in the light of the results presented above, we must envisage a form of supra-village organisation of blade production for these Blicquian communities of Hainaut. Blade knappers would have moved from one settlement to another and from one household to another. They would have carried preforms and blades and would have frequently finished the process of knapping locally. The development of simple production during the BQY/VSG culture could be closely linked to this specialised organisation of the production of lithic tools. With the development of domestic flake production, it would have been possible to do without specialist blade knappers to obtain the thick flakes produced at the beginning of the blade *chaîne opératoire*. From this perspective, the example of the two BQY sites at Irchonwelz attributed to the early chronological stage would prove particularly convincing (Fig. 14).

productions	blade	simple	indeterminate
IBF Feature 9	67	4	28
IBF House 20	52	4	44
IBF House 10	45	8	47
IBF House 30	45	5	50
ITC 73	21	72	7

Fig. 14 – Quantitative representation of the two kinds of production on the sites of Irchonwelz 'la Bonne Fortune' and 'le Trou al Cauche' in % of number.

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Prehistoric flint mine detection by airborne laser scanning (ALS). Experiences from Poland 2011–2015

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Katarzyna RADZISZEWSKA & Michał SZUBSKI

Abstract

Research on flint mining in Poland has a long history. It started at the beginning of the twentieth century through the pioneering research by S. Krukowski and J. Samsonowicz. Over the years, successive generations of Polish researchers continued investigations of prehistoric extraction and distribution of rich siliceous deposits in the whole country. The advance of new methods of remote sensing opened the way to new research in this topic. The Institute of Archaeology of the University of Cardinal Stefan Wyszyński in Warsaw since 2011 has been researching prehistoric flint mining using airborne laser scanning (ALS, LiDAR). Within the projects, conducted in the years 2011 - 2015, we tested nondestructively a number of different mines from a chronological and geological point of view. At this time we have developed a research methodology, allowing remote sensing and verification of new sites and also increase our knowledge about mines already known.

Keywords: Flint mining, remote sensing, ALS, LiDAR.

Résumé

Les recherches sur les minières à silex ont une longue histoire en Pologne. Elles ont débuté au début du XXème siècle avec les recherches pionnières de S. Krukowski et de J. Samsonowicz. Au cours du temps, plusieurs générations de chercheurs polonais ont perpétué les recherches sur les sites d'extraction préhistoriques, ainsi que sur la répartition des roches siliceuses de bonne qualité, sur l'ensemble du territoire. Les avancées des nouvelles méthodes de télédétection ont ouvert la voie à de nouvelles recherches dans ce domaine. L'Institut d'Archéologie de l'Université Cardinal Stefan Wyszyński à Varsovie, a développé, depuis 2011, un projet de recherches sur les minières à silex préhistoriques en utilisant la détection laser aéroportée (airborne laser scanning, LiDAR). Dans ce projet qui s'est déroulé entre 2011 et 2015, il a donc été possible de travailler de manière non destructive sur différents sites miniers, sur les aspects géologiques et chronologiques. Aujourd'hui, nous avons développé une méthodologie qui nous permet la télédétection et la vérification de nouveaux sites, tout en approfondissant notre connaissance des sites déjà connus.

***Mots-clés** : exploitation minière du silex, télédétection, ALS, LiDAR.*

1. Introduction

The first prehistoric flint mine in Poland was discovered by J. Samsonowicz and S. W. Krukowski in September 1921. This was the site 'Borownia' in Ruda Kościelna, Ostrowiec Świętokrzyski district. However, the explorers were not able to properly interpret all observed facts and found the site to be remnants of rich flint workshop (KRUKOWSKI, 1921, p. 162-163, fig. 10). A year later – July 19, 1922 – J. Samsonowicz discovered Neolithic mines of banded flint in Krzemionki, Ostrowiec Świętokrzyski district. This object, which was destroyed by limestone mining, enabled the observation of not only surface materials or relief of the spoil tips, but also underground mining. The observations made by J. Samsonowicz made it possible to reinterpret the site 'Borownia' discovered a year earlier and consider it as a remnant of prehistoric flint mine (SAMSONOWICZ, 1923, p. 23). The great and well-preserved site in Krzemionki in the interwar period was a centre of research on prehistoric flint mining in Polish Lands. S. Krukowski, who conducted his research at that time, noted that the relation between the types of underground excavation and mining heaps is so large, that a specific type of heap enables to infer the characteristics of the corresponding underground (KRUKOWSKI, 1939, p. 12, 27-33). However, creating accurate plans of large site of varied terrain relief was beyond the financial and organisational capacity.

2. History of topographic survey at flint mines in Poland

The first topographic plan of prehistoric flint mine was made in 1940 by W. Zelkewicz and T. Żurowski, under the supervision of S. Krukowski, in the area of much smaller site in range Zbuczi in the village of Łazariwka, located in the upper Dniester basin, in the present-day western Ukraine. The 1:1000 scale map, with a contour interval of half a metre, covered the whole site about 230 metres long and about 16 metres wide (SYTNIK, 2014). Unfortunately, this map has disappeared into war containment and the relief of the site has never been the subject of detailed analyses.

The contour plan of 'Krzemionki' mining field on a scale of 1:200 with a contour interval of 25 cm was created in 1947-1948 by the Councillor of the Central Office of National Measurements Ing. R. Gizowski (SAWICKI, 1948, p. 123). That plan was so large and complicated that was plotted only in 1953. Finally, it consisted of 45 sheets in a format close to B2, with 2480 pits, recognised as remnants of prehistoric shafts. It turned out, however, that the amount of information carried by such plan surpassed the analytical capabilities of the researchers. The idea of its detailed analysis crystallised only in the eighties of the last century (BUDZISZEWSKI, 1990). Such a task was undertaken by W. Borkowski in his doctoral dissertation in 1993 and published two years later (BORKOWSKI, 1995). At the beginning of the nineties, the researcher realised another similar project. In the newly discovered mine of erratic flints 'Rybniki-Krzemianka' in Kopisko, Białystok district, a detailed altitude situational plan of the site was created and analysed (BORKOWSKI, 2005).

The time-consuming nature of this type of work, with the simultaneous analytical limitations of poorly computerised level of technology, caused similar studies to be discontinued over the next dozen years. Back to them made only a breakthrough due to the development of airborne laser scanning (ALS, LiDAR).

3. Airborne laser scanning (ALS) as a new tool to investigate flint mines relief

Airborne laser scanning (ALS, LiDAR) is a method of acquiring spatial data using laser measurements for remote sensing and analysis of objects with preserved terrain relief. In archaeology this method is used recently, the first projects of this type date back to 2000. In recent years, with the development of technology and increasingly cheaper access to data, it has become the leading, non invasive method of archaeological research in wooden areas (CRUTCHLEY & CROW, 2010; DONEUS & BRIESE, 2011; HOLATA & PLAZAK, 2013; BANASZEK, 2015).

The ALS technology utilises interoperable devices – a laser beam emitter, a laser beam distribution module, a reflections detector and a GPS receiver as well as gyroscopic device to determine pitch, roll and heading of the plane correlated with GPS base station to determine the exact position of the scanner. This makes it possible to calculate the location in which the laser beam bounced off the obstacle surface and save it in the XYZ space coordinate system. As a result of post processing, a cloud of all points registered by the scanner is obtained (KURCZYŃSKI, 2015, p. 59-60). The next step is the point classification. It allows extracting the reflections that have reached the ground. In the case of archaeology, this is an extremely important element of the process, as part of the information on landform can be lost, or even false objects can be generated during the classification (OPITZ, 2016, p. 37-44).

On the basis of classified point cloud, a digital terrain model (DTM) is generated. This is a numerical representation of the terrain surface that allows determining the height of each point upon the topographic surface. The model can be generated in two ways – as a grid of squares (GRID) and as irregular triangles (TIN). In the case of the TIN model, the points are not subjected to interpolation –

so it is more 'real' land mapping (BORKOWSKI, 2015, p. 110-111). Archaeological analyses use different DTM visualisation methods. Apart from the standard hillshading, which involves lighting the 3D model from any chosen direction, other algorithms are also used. They represent a terrain relief illuminated from multiple directions at the same time or completely independent of light, using geometric relationships between adjacent measurements (KOKALJ & HESSE, 2017).

In order to know the quality of a scan, the most commonly used is the nominal number of measurements per square metre. As our current experience shows, four points are enough for the archaeological application. However, this problem is much more complex. The most important is the number of measurements that have reach the ground surface. It depends on the scan parameters and the type of forest cover. As the scan is made more perpendicular to the surface, the greater is the penetration of the laser. However, reducing the scan angle increases its price because more flights are required. Typically, a scanning angle of 20 to 30 degrees from the vertical is used. Another important value is the size of the laser spot - the greater is the better for the penetration of the plant cover. Later, however, a terrain model with a pixel size smaller than the spot diameter used for scanning cannot be generated. A scan with a speckle diameter of about 40 cm is considered as a good compromise. In addition to scanning parameters, a vegetative cover also has impact on the data quality. Therefore, its term should be chosen in such a way that the least possible obstacles appear in the way of the laser beam. In Central Europe, it is early spring or eventually late autumn.

The additional information that can be obtained from the ALS data is the laser return beam intensity (Fig. 1). This method is applicable

Fig. 1– Chocolate flint mining field 'Przyjaźń' in Rzeczków, Radom district. Comparison of digital terrain model (a) and visualisation showing intensity of laser return beam (b) on the site with a ploughed surface. The line is indicating the area where flint artefacts are present.

for open area analysis, also for remote sensing of archaeological objects, similar to vegetative changes in aerial photography (CHALLIS *et al.*, 2011). Unfortunately, in spite of good efficiency in the analysis of geological structures, this method is not effective for archaeological sites (BENNET, 2014, p. 31- 32).

In the realities of Polish archaeology, besides costly commissioned flights, the data provided under the governmental project IT System of the Country's Protection Against Extreme Hazards (ISOK) may be used. The primary goal of this project, co-funded by the state and the European Union, was to create a flood risk map based on precision altitude data obtained by airborne laser scanning (MAŚLANKA & WĘŻYK, 2015). However, the interest in the data obtained during it turned out to be so great that in the course of implementation it was decided to extend it and cover the entire territory of the country. Scan quality is 12 points per square metre in urbanised areas and four or six points per square metre in other areas. Most of Poland's surface, including forested areas of flint outcrops,

Fig. 2 – Location of surveyed areas of the prehistoric flint mining conducted by the Institute of Archaeology of the University of Cardinal Stefan Wyszyński in Warsaw in the years 2011-2015, in the background range of available airborne laser data provided by the ISOK project. Circle – grant project (ordered scans); rhomb - self project (ISOK data).

are scanned in the standard with parameters: ≥ 4 points per m^2, scanning angle ≤ 25°, laser beam spot diameter ≤ 0.5 m (KURCZYŃSKI *et al.*, 2015, p. 31-32). Data provided within the ISOK project can be purchased (or obtained free for educational and scientific purposes) in the form of a LAS point cloud that can be further processed. By the middle of 2017 ALS data for the area of 92 % of Poland was made available in this way (Fig. 2). The data derived from the ISOK program is available in the public domain: http://mapy.geoportal.gov.pl/wss/service/WMTS/guest/wmts/ISOK - a raster image of the simplified DTM of the area of Poland, allowing for the initial insight into micro-topography of archaeological sites before taking any fieldwork.

4. ALS SURVEY OF THE POLISH FLINT MINES

Taking advantage of emerging opportunities at the Institute of Archaeology of the Cardinal Stefan Wyszyński University in Warsaw, a number of tasks were implemented in the years 2011-2015 using the effects of airborne laser scanning. First – in 2011 – was examined the outcrop of banded flints in the Central Poland over the lower Kamienna River, under the grant of the Ministry of Culture and National Heritage (MKiDN): Research of the prehistoric flint mines using LiDAR. In 2013 another grant of the MKiDN was completed: Cataloguing of prehistoric flint mines in different environmental conditions. In its framework an area of chocolate flint exploitation from Upper Jurassic limestone of Central Poland and Cretaceous erratic flint from Quaternary moraines in north-eastern Poland (Knyszyn Forest) were compared. Scanning in the above projects was performed by the Polish company MGGP Aero. Remote sensing measurements were made using the Lite Mapper 68000i system. Scanning standards assumed a sample density of 4 pts/m^2 with the accuracy of altitude measurement ≤ 15 cm and continuous reflection readings for four ranges. On the basis of such data, the digital terrain model (DTM) in GRID ASCI format was created, at a resolution of 0.5 m and altitude accuracy of h ≤ $\pm$ 0.25 m, as well as digital surface model (DSM) of the same parameters. In the next two years, as a part of research were analysed the remnants of early modern Jurassic flint mining in the vicinity of Cracow and traces of sedimentary siliceous rocks (siliceous marls) exploitation in Cergowa, Carpathian Mountains. In both cases the basis of the study was the data obtained from the ISOK program. In 2015, an attempt was also made to carry out a detailed analysis of the topography of the 'Borownia' banded flint mining field. All these works allow for an initial assessment of the capabilities of airborne laser scanning for the studies on prehistoric flint mining.

It turned out, that the ALS digital terrain model (DTM) identifies many geological structures. While the possibility of observing the course of rocks in the Carpathians is easy to account, it is difficult to explain the fact that DTM also maps the course of layers of Jurassic limestone on the north-eastern margin of the Świętokrzyskie Mountains. Jurassic rocks are covered there by a thin (1-2 m) layer of Quaternary formations, which should result in ground levelling and hide the eroded rock surface. Nevertheless, there are slight patterns of successive limestone layers of varying resistance, unnoticeable on the surface but perfectly clear in the micromorphology of the terrain (Fig. 3). In this situation it is easy to track the layers containing flints and look for traces of their prehistoric exploitation. It is also easy to record all the disturbances in the course of layers that reveal even minor tectonic faults. This allows to clarify and to verify a number of previous views on the geological structure of this area. For example, it turned out that the detailed reconstruction of the geological structure of the 'Krzemionki' reserve area (MICHNIAK, 1992; BORKOWSKI, 1995, p. 41-53) resulting from the research in early nineties, in many crucial points is quite erroneous. All of the faults slitting the mining field that were supposed to have meridian run actually run latitudinal.

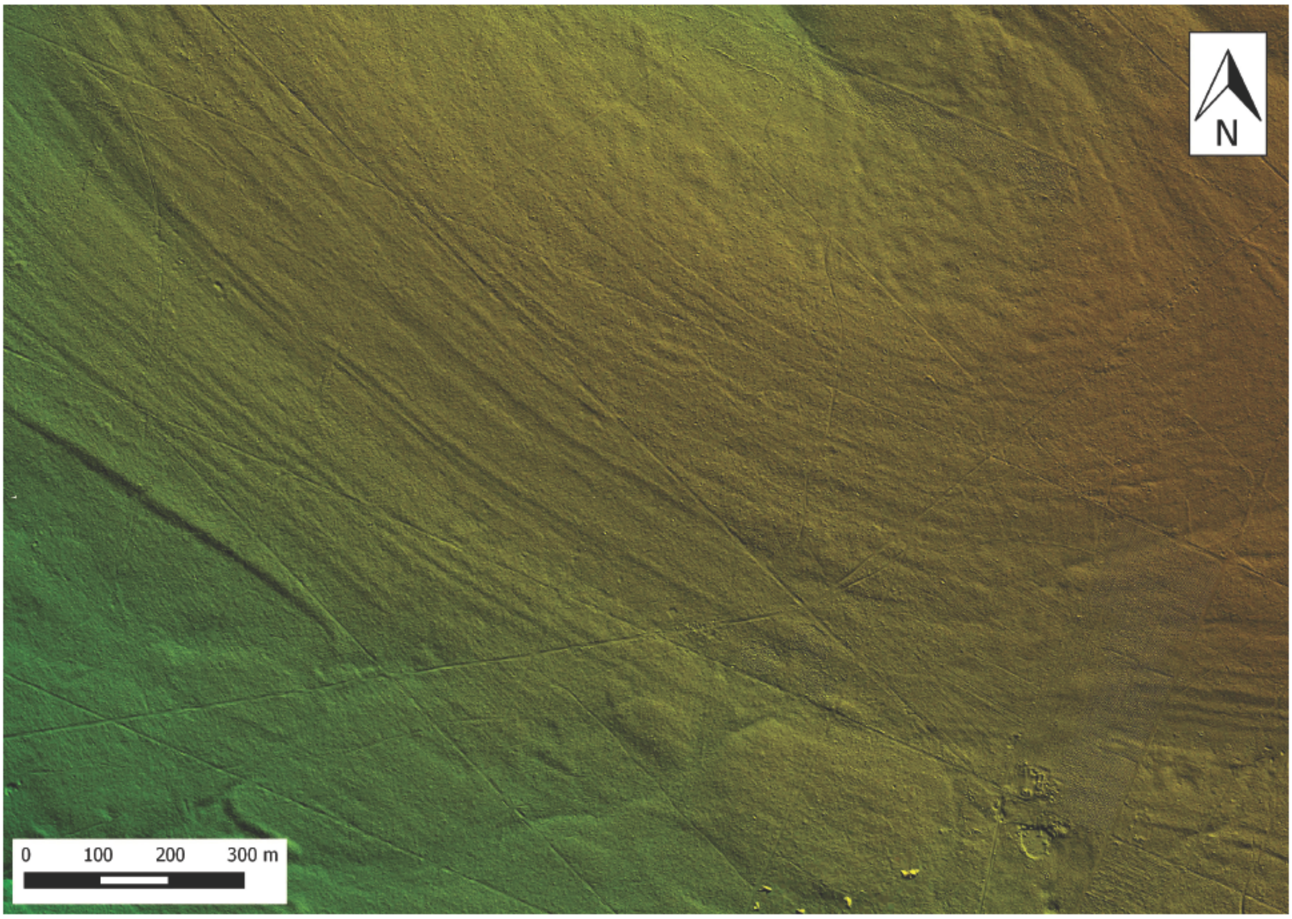

Fig. 3 – Digital terrain model of south-eastern part of Magonie-Folwarczysko basin showing the Oxfordian and Kimmeridgian limestone layers course containing banded and chocolate flints.

The data on geological structure was obtained not only from the analysis of surface microrelief of the area. They also appear in the visualisation of reflection intensity. For example, the anomalies observed in the vicinity of the 'Zele' mining field of chocolate flints in Wierzbica, Radom district, look like Pleistocene polygonal structures.

The digital terrain model obtained by airborne laser scanning allows identification of various types of flint mining remains. The simplest to interpret are large, isolated mines, such as the chamber mines on 'Krzemionki' mining field (MIGAL, 1997, p. 318-319, 322-324). They have round heaps reaching up to one metre in height and scattering up to over a dozen metres from the centre of the shafts (Fig. 4). Sometimes they are not omnipresent, but consist of two half-shed heaps of different heights. Several of such objects were excavated (ŻUROWSKI, 1962; BORKOWSKI & MIGAL, 1988; BĄBEL, 2015, p. 63-86), therefore we know that the heap size is limited because most of the debris was deposited in the mine's underground. Generally, the relief of this type of objects is similar to the medieval and modern metal ore mines (CASAGRANDE, 2013; CEMBRZYŃSKI & LEGUT-PINTAL, 2014; KAPTUR, 2014).

Equally obvious is the form of small quarries facing the slope, where the heaps were naturally dropped down. Such objects were identified in the DTM of the north-eastern part of the mining field of banded flint 'Skałecznica Duża' in Teofilów, Opatów district (JAKUBCZAK, 2012). They range from a few to over a dozen metres wide, with niches of less than one metre deep. Several similar objects have also been identified to the north-western extremity

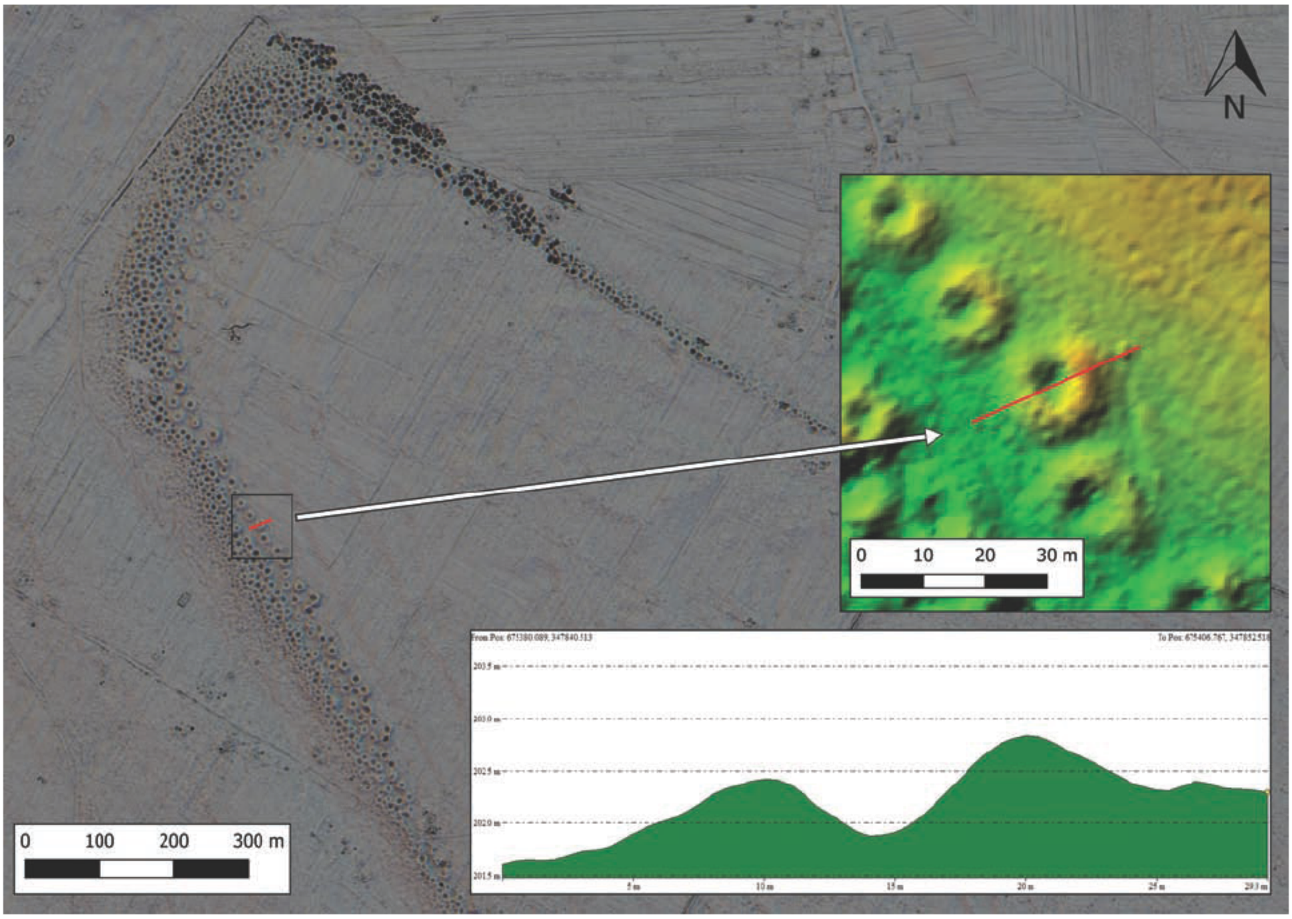

Fig. 4 – Digital terrain model of banded flint mining field 'Krzemionki', Ostrowiec Świętokrzyski district. Visualisation of chamber mines surface relief.

of the Rybniki-Krzemianka mining field in Kopisk, Białystok district, where Cretaceous flints from Quaternary moraine were exploited (BORKOWSKI, 2005; SZUBSKI, 2016). Analogous objects, but of a much more pronounced form, are also known from the modern Jurassic Cracow flint quarries, mining for the purposes of gunflint production in Mników (Fig. 5) and the northern rim of Zelków, Krakow district.

With a completely different relief we are dealing on sites related to the exploitation of banded flint in mines with large niches or in chamber and pillar mines (MIGAL, 1997, p. 317-323). We know them from the sites of 'Krzemionki', 'Borownia' and 'Korycizna', Ostrowiec Świętokrzyski district. At the first of these sites, several of such objects were excavated (SAŁACIŃSKI, 1988; BĄBEL, 2015, p. 56-66), so we have come to know the relation between the method of exploitation and surface relief. The heaps of mines create here a relatively high, several-centimetre embankment, which depicts the depressions of particular shafts (Fig. 6). Such image is very impressive, but not easy to explain in detail, because many of the observed hollows raise doubts whether they are the remnants of shafts or accidental forms at the contact of several heaps. There is also no certainty that heaps do not mask some of the older shafts.

From the outcrops of the banded flint we know one more kind of surface micromorphology of the prehistoric flint mine. These are low, several dozen centimetres in height embankments, stranded out from the environment like scabs. They have a weak surface relief, in which it is impossible to separate the depressions of particular mining objects. Such relief characterises sites 'Krunio' (Fig. 7)

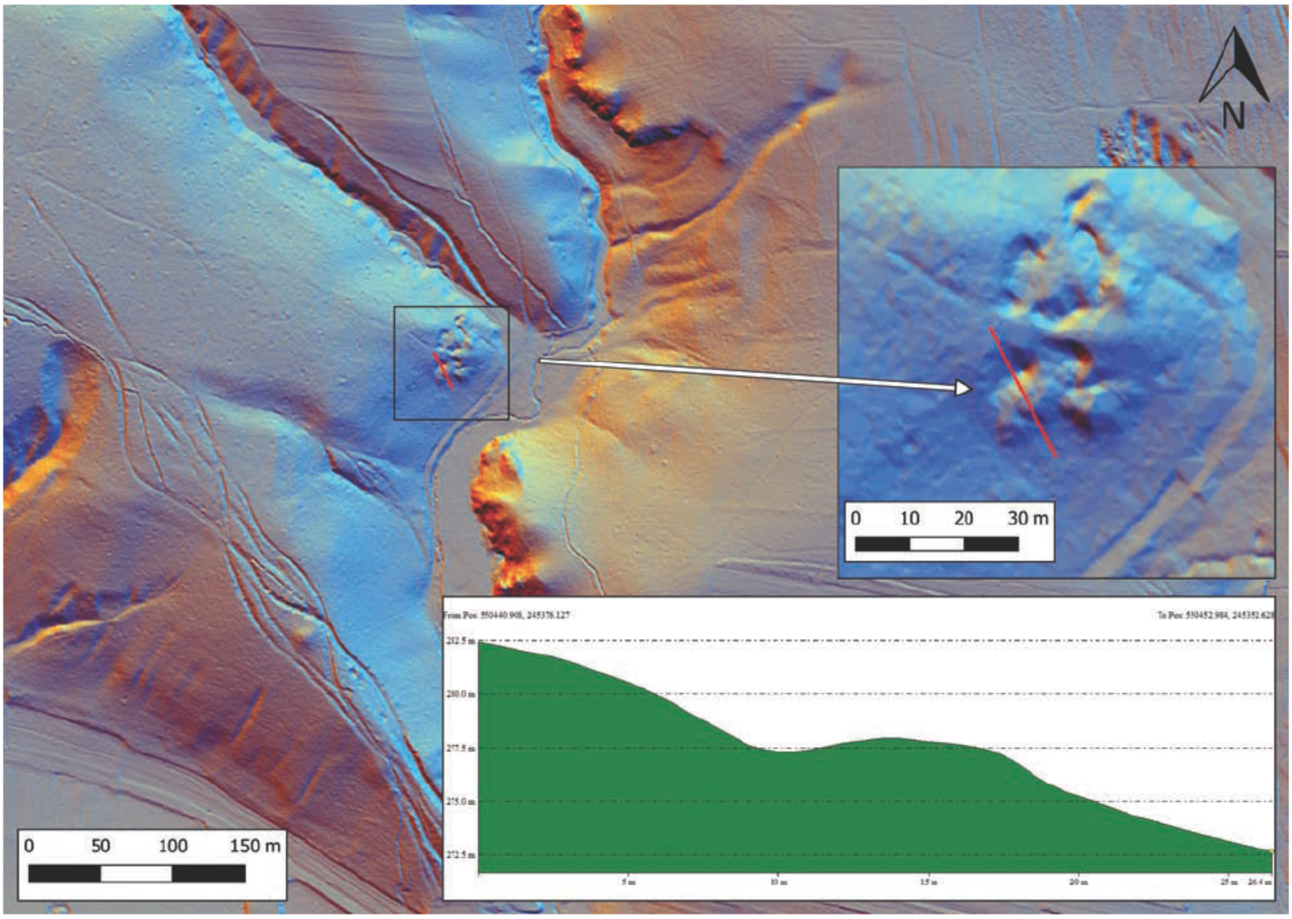

Fig. 5 – Digital terrain model of modern Jurassic Cracow flint quarries in Mników, Kraków district. Visualisation of present surface relief with modest quarries.

and 'Nowa' in the Ostrowiec Świętokrzyski district. It is impossible to say today whether this relief is the result of some specific method of exploitation, local deposit conditions or subsequent damage by the agriculture.

It seems that the most frequently observed anthropomorphic relief on the sites related to the flint sourcing is the surface of extremely varied but not very deep relief. Among local hills and hollows, regular circular depressions appear as if they are the scars of the youngest generation of objects. However, for most areas, a digital terrain model generated by scanning at a resolution of four dots per square metre does not allow for reliable localisation of particular mines, and it may not be possible even with more accurate plans. Such relief was probably created during the exploitation of raw materials in small pit mines. We know it from sites with very different geological conditions. Both, from the sites related to the exploitation of flints from Quaternary moraines (SZUBSKI, 2016; Fig. 8), as well as banded flint from Jurassic limestone in most of the 'Skałecznica Duża' area (JAKUBCZAK, 2012) or Jurassic flint near Kraków in early modern mines in Karniowice, Kraków district.

The types of anthropogenic relief of flint mines surface identified in research practice of Institute of Archaeology of Cardinal Stefan Wyszyński University in Warsaw certainly do not exhaust all possibilities. The only published analyses of this type of sites, conducted using airborne laser scanning imaging in the south-western Pyrenees in Spain reveal a picture unknown from Polish sites (TARRIÑO *et al.*, 2011; ORÚE BELTRÁN DE HEREDIA, 2013; TARRIÑO *et al.*, 2014). It can therefore be presumed that the above-mentioned catalogue will have to be supplemented many times.

It is important to note that the anomalies observed in the digital terrain model must

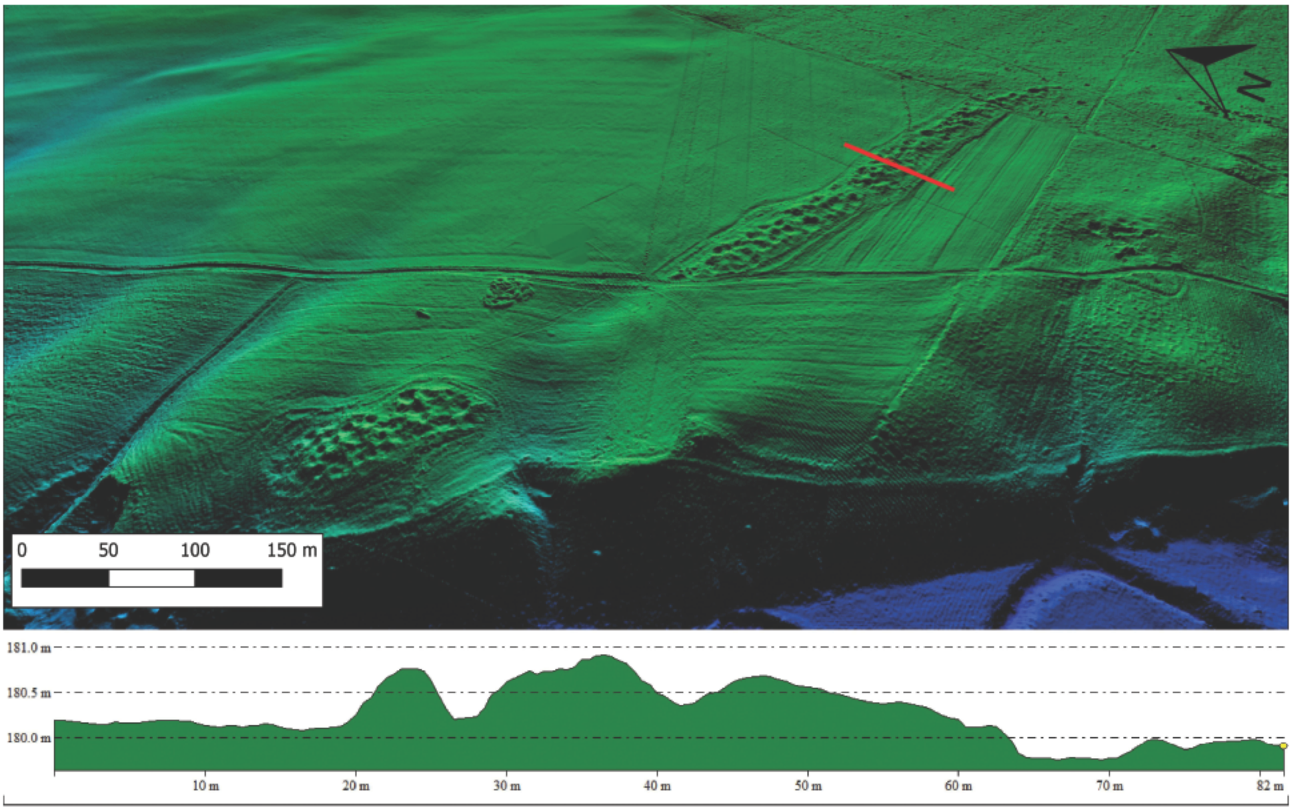

Fig. 6 – Digital terrain model of banded flint mining field 'Borownia' in Ruda Kościelna, Ostrowiec Świętokrzyski district. 3D visualisation of prehistoric flint mines surface relief.

always be verified in the field. Objects with a very similar surface microrelief may be formed not only by the use of flint sourcing, but also by the activity of animals. Similar in form are also, for example, the complexes of badger sets. Luckily, they are usually smaller in size than the prehistoric mining sites. However, from the Knyszyn Forest in north-eastern Poland a complex of badger sets of 50 x 25 metres is known.

An additional difficulty in identifying the relief of the prehistoric mining sites is that we must take into account not only the differences arising from various types of mining activity or deposit conditions, but also differences in the degree of damage caused by later economic activity, mainly agricultural. Observations made during our work revealed that anthropogenic relief is impermanent and easily can be totally destroyed. By far the most known sites related to the exploitation of flint show a relief completely aligned with later ploughing!

Reflecting on the combination of the flint mining sites relief images and its difference with the remnants of other stone materials exploitation, we must note that in the flint mines a small amount of material is obtained in relation to the size of the work being carried out. While as a result of the exploitation of sand, clay or limestone there are distinct niches in exhausted deposits, in the case of flint we rather observe the increase in volume of heaps resulting from the fragmentation of gangue. Certainly, the remains of the siliceous layer rocks exploitation will be different. Some ideas can result from the studies on Neolithic exploitation of metabasalts, conducted in recent years in the Jizera Mountains in Czech Republic (PROSTŘEDNIK *et al.*, 2005; ŠIDA *et al.*, 2013; ŠIDA, 2014).

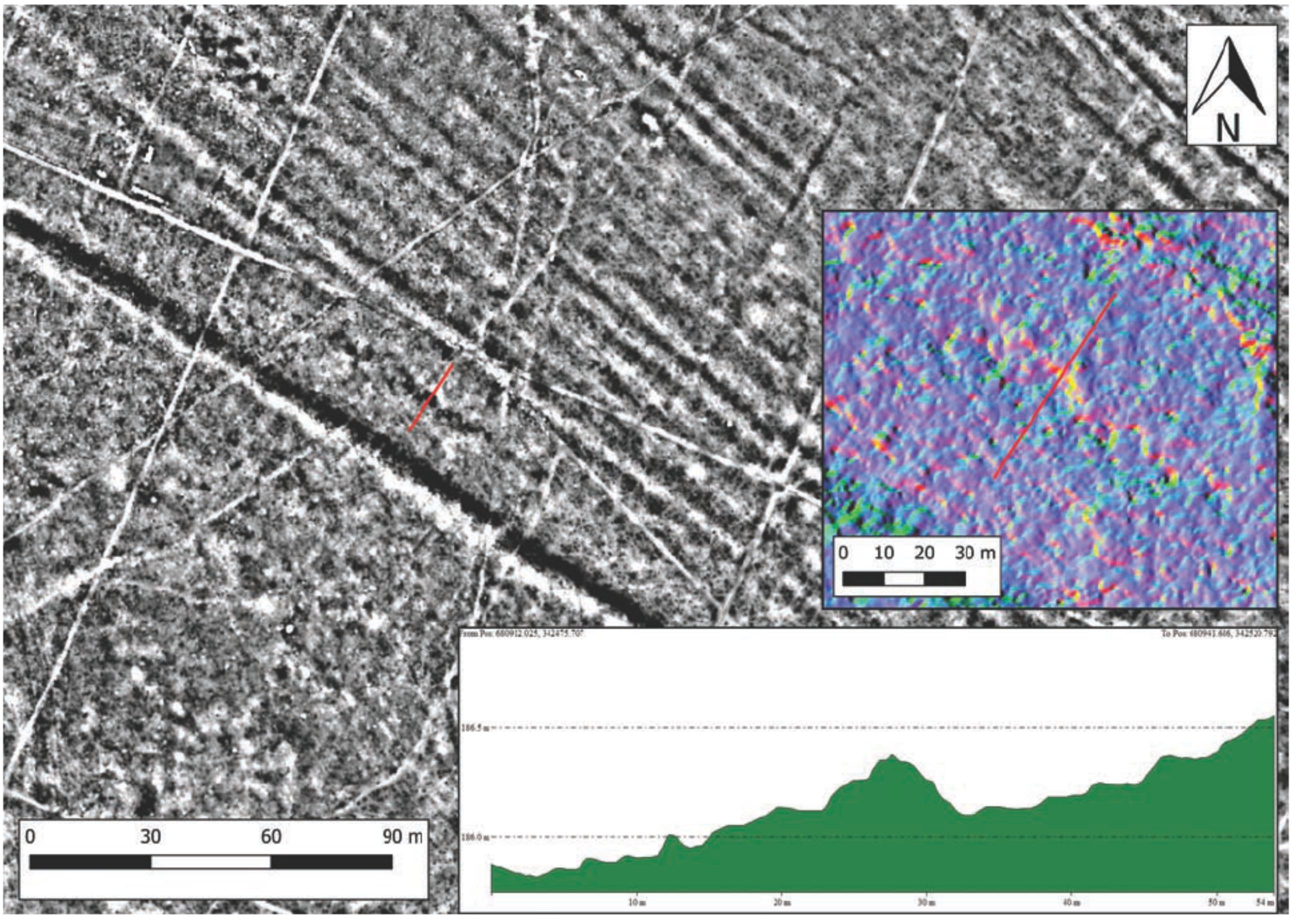

Fig. 7 – Digital terrain model of banded flint mining field 'Krunio' in Łysowody, Ostrowiec Świętokrzyski district. Visualisation of prehistoric flint mines surface relief.

5. AN ATTEMPT OF DETAILED STUDY OF FLINT MINE RELIEF

The effects of airborne laser scanning also have been recently tried for a detailed analysis of a single mining field. This test was carried out on the banded flint exploitation site 'Borownia' in Ruda Kościelna, Ostrowiec Świętokrzyski district (RADZISZEWSKA, 2015). Although this is the first prehistoric mining site discovered in Poland, it was never excavated. Among the surface materials dominant are the remnants of bifacial axes production in the Early Bronze Age. The exploitation field extends for 700 metres long and 30-50 metres wide, and is centred on a north-west – south-east axis (BUDZISZEWSKI & MICHNIAK, 1983/1989, p. 164-166). The estimated area of the entire mining field is about 2.7 hectares, of which an anthropogenic post-mining relief has been preserved in an area of approximately 1.5 hectares (Fig. 6).

Standard ALS data (4 pts/m^2, dot Ø 0.5 m) allowed the creation of a three-dimensional model of the site, related to the global coordinate grid. As a result, 192 depressions that could be identified as remnants of prehistoric mining shafts were identified on fragments of the field with preserved mining relief. Referring to the work of W. Borkowski (1995, p. 101-124) Thiessen polygons were applied to the visualisation of the terrain (Fig. 9a). On the basis of obtained results, the neighbouring shafts were determined and the distance between them was calculated. Subsequently, the maximum exploitation range was calculated by measuring the distance from the nearest concavity of adjacent shaft, as well as the maximum exploitation range by the average distance between adjacent shafts, the area of particular mining units, and volume (Fig. 9b) and maximal height of heaps (RADZISZEWSKA, 2015, p. 85-155). In order to determine the numerical representations of shafts for the resulting object

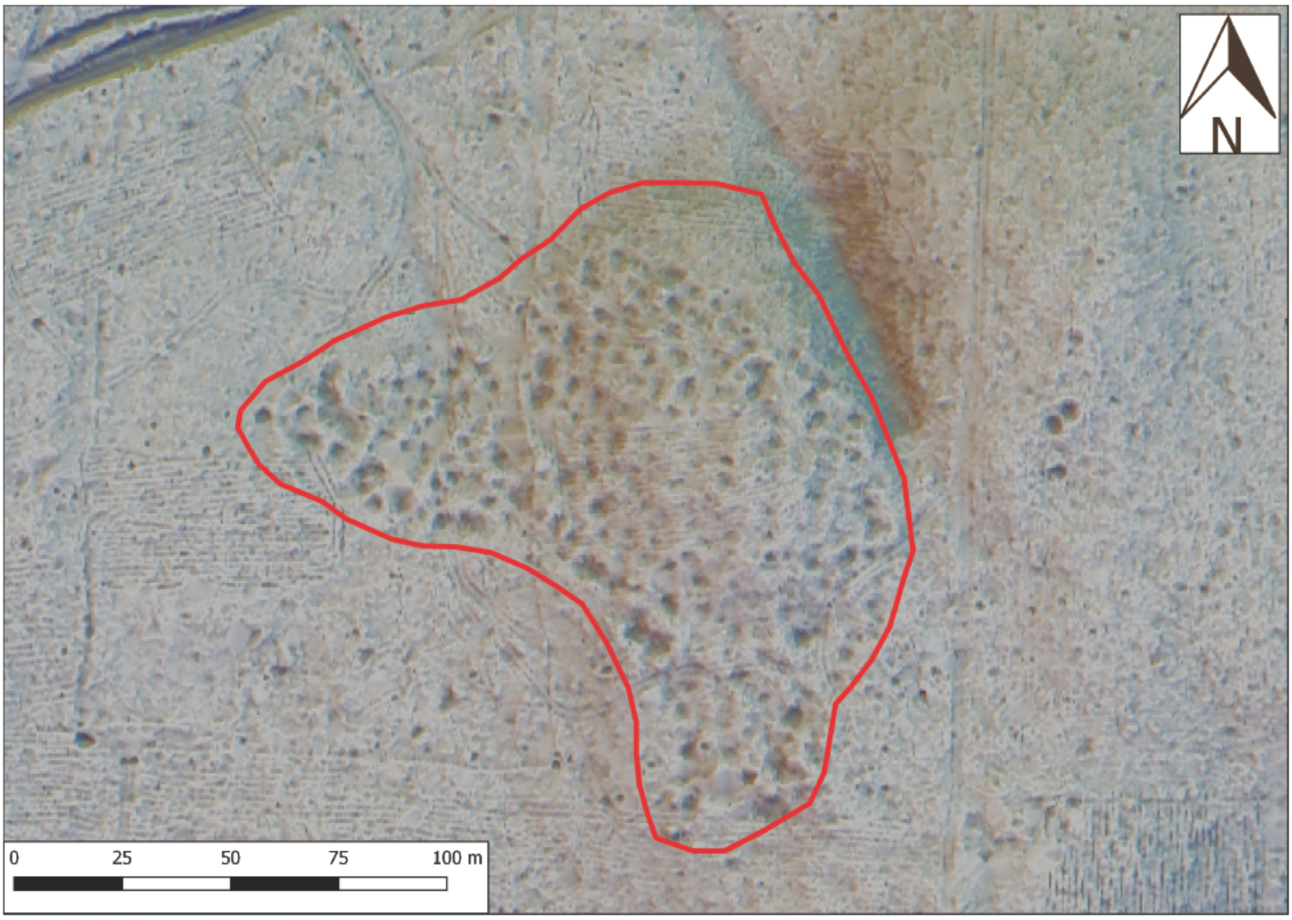

Fig. 8 – Digital terrain model of Quaternary moraine flint mining field 'Ogrodkowo I' in Kopisk, Białystok district. Visualisation of prehistoric flint mines surface relief.

classes, statistical methods were used. Performed analyses in conjunction with the results of ground penetrating radar sensing and electrical resistivity tomography has allowed presenting a number of hypotheses regarding the character of the whole site.

According to geophysical studies, the dip angle of rock layers in the area of the mining field was determined to be 5-10 degrees in the north-east direction (MIESZKOWSKI *et al.*, 2014, p. 127-128). The mines found here reached a depth of 5-6 m (MIESZKOWSKI *et al.*, 2014, p. 128). There was only one case of anomaly that could be a reflection of a mining pit with a depth of 8 m (WELC *et al.*, 2014, p. 154). The maximum exploitation range, calculated according to the distance from the concavity of the adjacent shaft, ranged from 1 to 6 m. However, it is worth mentioning that only for 24 shafts this value was over 4 m, and only 5 of them were assigned a value exceeding 5 m (RADZISZEWSKA, 2015, p. 119-126).

The results of the analyses, compiled with the results obtained in 1993 by W. Borkowski for the 'Krzemionki' mining field (BORKOWSKI, 1995), suggest that in the case of 'Borownia' we are dealing with the occurrence of pit and niche exploitations. The existence of pillar and chamber mines can be excluded (RADZISZEWSKA, 2015, p. 156-157).

A summary of all the data shows that the shaft system is not compatible with the course of the natural layers documented by geophysical surveys on the mining field. The objects are grouped on parallel lines of cuts, as the arrangement of several shaft units with similar characteristics, which are often located around larger objects. In the north-western part of the site clearly stands out a division of the area into three such concentrations (Fig. 9), in the south-eastern part 8-10 groups can be distinguished. J. Samsonowicz in his classic geological studies postulated the existence of a fault dislocation located alongside the Kamienna River, in the immediate vicinity of the mining field 'Borownia' (SAMSONOWICZ,

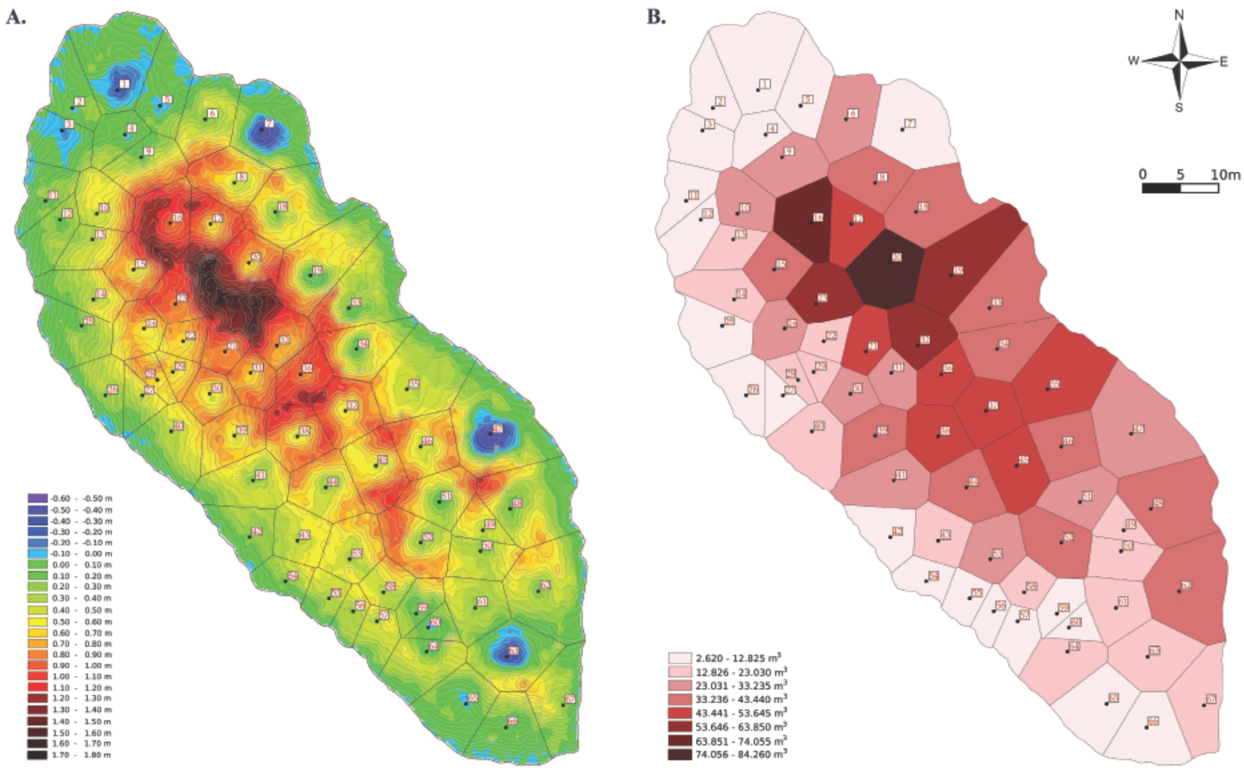

Fig. 9 – North-western part of banded flint exploitation field 'Borownia' in Ruda Kościelna, Ostrowiec Świętokrzyski district. Thiessen polygons overlying 3D surface model (a) and volume measurement of the individual heaps (b).

1934). Such a fault must be accompanied by a series of small transverse dislocations, running latitudinaly. Possibly, karstic processes running inside modified the rock mechanics conditions at the discussed site. This can only be confirmed by more accurate geophysical studies or excavation.

6. CONCLUSIONS

Studies conducted by the Institute of Archaeology of Cardinal Stefan Wyszyński University in the years 2011-2015 revealed that the data obtained by the ALS allow evaluating the geological conditions and identifying the remains of prehistoric and modern flint mining in various geological-environmental conditions. In spite of the technological advances, detection of the prehistoric siliceous rocks exploitations remains a task requiring certain qualifications, and distinguishing them from the traces of other human or even animal activity is possible only during field verification. Detailed analysis of the surface relief of the prehistoric mining sites allows hypothesising the methods used in their exploitation; however, such analyses usually require scanning in higher than the standard resolution.

Text translated by Tomasz MYŚLIWIEC.

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Mapping the radiolarite outcrops as potential source of raw material in the Stone Age: Characterisation of Polish part of the Pieniny Klippen Belt

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Abstract

Radiolarite is a siliceous rock originated from the deep-sea sedimentation of radiolarian skeletons. It is a well-known raw material, commonly used during the Stone and Early Bronze Age in Europe. It is diversified in colour and other macroscopic features. The richest and most important deposits in Poland are located in the Pieniny Klippen Belt, itself a part of a geological unit which appears also in other countries in the Carpathian Mountains (Romania, Ukraine, Slovakia and Austria). Excavations conducted in this area since 1970s by P. Valde-Nowak and J. Rydlewski revealed abundant evidence of Palaeolithic processing workshops and camps. Exploitation of the radiolarite took place in the Pieniny Klippen Belt since the Middle Palaeolithic through the Upper Palaeolithic, which was confirmed by further studies by P. Valde-Nowak in Obłazowa Cave. The distribution of radiolarite materials is documented in Poland since the Middle Palaeolithic until the Early Bronze Age, but occurred mostly during the Late Palaeolithic.

Keywords: radiolarite, Stone Age, Pieniny Klippen Belt, raw material, Poland.

Résumé

La radiolarite est une roche siliceuse, composée essentiellement de squelettes de radiolaires, formée dans les sédiments marins profonds. C'est un matériau bien connu, communément utilisé en Europe durant la Préhistoire et l'Age du Bronze ancien. Sa couleur, ainsi que d'autres caractères macroscopiques, sont variables. Les gisements les plus riches et les plus importants, en Pologne, sont situés dans la zone du Pieniny Klippen. Ils font partie d'une formation géologique qui existe aussi dans d'autres régions des Carpathes (Roumanie, Ukraine, Slovaquie et Autriche). Des fouilles menées dans cette région depuis les années 1970 par P. Valde-Nowak et J. Rydlewski ont mis au jour de riches vestiges d'ateliers de taille et de campements paléolitiques. L'exploitation de la radiolarite a lieu dans la zone du Pieniny Klippen du Paléolithique moyen au Paléolithique supérieur, ce qui a été confirmé par les travaux de P. Valde-Nowak à la grotte d' Obłazowa. Bien que la distribution de mobilier en radiolarite est attestée en Pologne du Paléolithique moyen jusqu' au Bronze ancien, son utilisation principale a lieu au cours du Paléolithique supérieur.

Mots-clés *: radiolarite, Préhistoire, zone du Pieniny Klippen, matière première, Pologne.*

1. Introduction

Radiolarite is a siliceous rock originated from the skeletons of radiolarians in a deep-sea context. Radiolarites are present in many geological units and were commonly used during the Stone and Early Bronze Age in Europe. In some regions it was the main raw material.

In Poland there are a lot of well-known siliceous rocks of a good quality that were used by prehistoric societies - especially flints, but also radiolarites. One of the most important sources of good quality radiolarites in Central Europe is the Pieniny Klippen Belt (PKB) in the Carpathians, also in Poland.

This paper presents the problematics of the use and significance of radiolarite in Poland. It focuses on the issue of the outcrops as potential sources that could be exploited by prehistoric societies, as well as on the scale of its use in the territory of Poland.

2. General description of radiolarites and their outcrops

Radiolarite originates from skeletons of radiolarians mainly below the Carbonate Compensation Depth level (CCD; KSIĄŻKIEWICZ, 1972; BOLEWSKI & PARACHONIAK, 1982; ELEKES *et al.,* 2000, p. 501). Radiolarites were formed in marine sediments starting at least from the Palaeozoic, and massively deposited in the Mesozoic (ELEKES *et al.,* 2000, p. 501). They also appear among the shallow rock deposits (BOLEWSKI & PARACHONIAK, 1982).

Radiolarite is characterised by its distinct, varied colour, gloss and degree of translucency that depends on genetic and post-diagenetic factors. Due to its properties comparable with flint and the richness of its sources, this rock was an excellent source of raw material for the Stone Age community. It is found in many parts of Europe, being in some places the basic raw material.

Deep-sea sediments occur in limited areas, including the Polish part of the PKB, where the manganese and steel-grey radiolarites are present (KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989b, 2009; PAWLIKOWSKI, 2009). Radiolarites of the transitional and shallow series are widespread in all areas (KOZŁOWSKI *et al.*, 1981; PŘICHYSTAL, 2013). These are red radiolarites, in various shades - liver-like, cherry red, or burgundy. They cover a range from waxy to dull, with a slight degree of transparency. This variety is most commonly found among Stone Age inventories and is the easiest to identify. There are also common green and yellow radiolarites of various shades (BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989b, 2009; PAWLIKOWSKI, 1992; CHEBEN & ILLÁŠOVÁ, 1997). Radiolarites are the subject of weathering processes, which affect their primary characteristics (RYDLEWSKI, 1989a-b; BRANDL *et al.*, 2013).

Primary radiolarite deposits occur in many of Europe's mountain ranges, e.g. the Carpathians, the Alps (KSIĄŻKIEWICZ, 1972; BIRKENMAJER, 1979; RYDLEWSKI, 1989b), as well as other geological units continuing on extensive areas. An important source of this raw material for Central Europe and for Poland is the already mentioned PKB, which is the geological unit that separates the Outer Carpathians from the Inner Carpathians. It occurs in the area between Romania in the south-east, eastern Slovakia, Poland (Podhale and Pieniny), Slovakia and Moravia (Vlarska Pass, White and Small Carpathians), Austria in the vicinity of Vienna, where alpine radiolarites are also recognised (BIRKENMAJER, 1979; RYDLEWSKI, 1989b; BRANDL *et al.*, 2013; PŘICHYSTAL, 2013). Layers of dark Ordovician-Carboniferous radiolarites occur in many mountainous areas of Europe, formed during the Palaeozoic mountain orogenic movements. These radiolarites are found e.g. in the Świętokrzyskie Mountains, the Sudetes, the Czech Massif, reaching the Pyrenees and Cornwall (PAWLIKOWSKI, 1992; MIGASZEWSKI *et al.*, 1999; PŘICHYSTAL, 2013, p. 68). Radiolarites are also found in the Outer Flish Carpathian, in the so-called Silesian and Sub-silesian series that continues along the Carpathian Arc in Poland and in neighbouring areas (KSIĄŻKIEWICZ, 1972; BOLEWSKI & PARACHONIAK, 1982). They were also used during the Stone Age (RYDLEWSKI, 1989a-b; VALDE-NOWAK, 2009). As for now, no archaeological researches have been conducted on the use of Tatra Mountains radiolarites (BOLEWSKI & PARACHONIAK, 1982; PAWLIKOWSKI, 1992, 2009) or these from the Świętokrzyskie Mountains (BOLEWSKI & PARACHONIAK, 1982; MIGASZEWSKI *et al.*, 1999).

In Hungary the richest outcrops of radiolarites are located in the Szentgal region (Szentgal type radiolarite), Bakonyscernye mountains, Gerecse (Lábatlan, Dunaszentmiklós, Tata) and in neighbouring areas (ELEKES *et al.,* 2000; PŘICHYSTAL, 2013, p. 129-131).

Radiolarites are also found within secondary deposits. They are readily available albeit in a limited size (RYDLEWSKI, 1989b; CHEBEN & ILLÁŠOVÁ, 1997). Examples of radiolarites that were acquired during the Stone Age from such sources are the Cretaceous 'Gliwice radiolarites' in Upper Silesia (FOLTYN *et al.*, 2009). They are also commonly found as boulders in the valleys of Slovakia, Moravia (Wag and Vlara rivers), Austria, Hungary (Danube Valley) and were used during the Stone Age (ELEKES *et al.*, 2000; PŘICHYSTAL, 2013; BRANDL *et al.*, 2015). In Poland, radiolarite from secondary deposits is recorded as well in archaeological material (e.g. from the Dunajec Valley: RYDLEWSKI, 1989a-b; WILCZYŃSKI *et al.*, 2014).

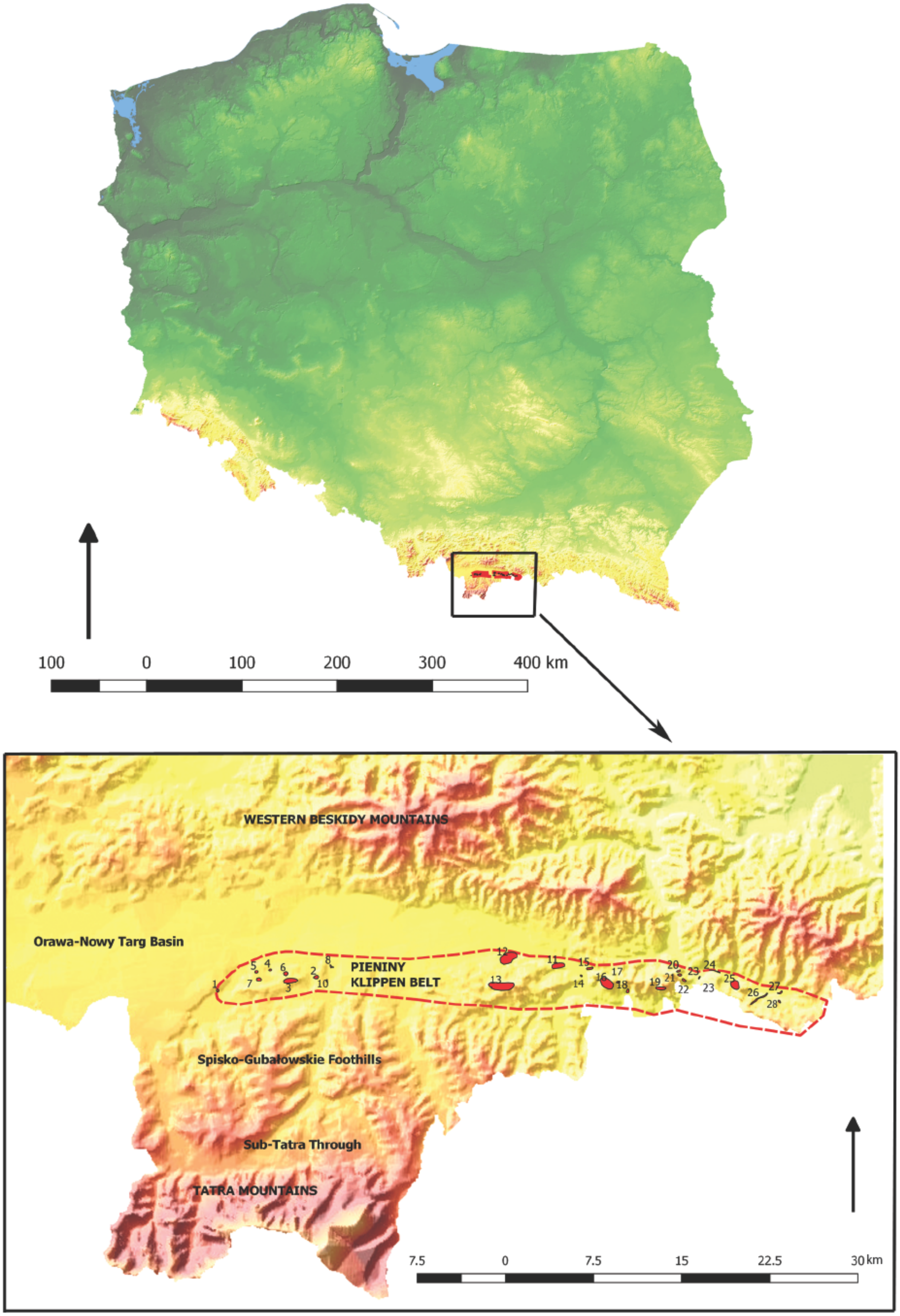
3. HISTORY OF RESEARCH ON THE POLISH RADIOLARITE INVENTORIES

Radiolarite is the subject of research since the first decades of the 20th century. Its outcrops have been identified in the Vlarska Pass in western Slovakia and the raw material was distinguished among the assemblages of sites located in Moravia and Slovakia (SKUTIL, 1947; KOZŁOWSKI *et al.*, 1981). At the same time discoveries of radiolarite mines were made in Austria and Hungary, showing its important role in the inventory of the Stone Age sites (TRNKA, 2011; BIRÓ & REGENYE, 2007). Also in Poland attention was paid to this raw material among Palaeolithic inventories (CZAPKIEWICZ, 1936; LINDNER, 1937). For a long time, the idea of long-distance, Slovak, Hungarian or Alpine origins of artefacts discovered at sites located in Poland was maintained (JURA, 1939; KOWALSKI & KOZŁOWSKI, 1959; GINTER, 1974; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989a-b). It was even more emphasised, that the products of Polish flint varieties were commonly found among the inventory of sites in the neighbouring areas, including the territory nearby the radiolarite outcrops (KOZŁOWSKI, 1957; POŁTOWICZ, 2007; WIŚNIEWSKI *et al.*, 2012, p. 398). Information about the deposits of radiolarite located in the territory of Poland, especially in the Pieniny Klippen Belt was included. However, it was emphasised that their quality was not equal to that of neighbouring areas (KOWALSKI & KOZŁOWSKI, 1959; BIRKENMAJER, 1979). In the 1970s and 1980s field research in the area of radiolarite outcrops in Poland in PKB and comparative laboratory studies revealed that this material was exploited and processed during the Stone Age (RYDLEWSKI & VALDE-NOWAK, 1977, 1978a, 1978b; KOZŁOWSKI *et al.*, 1981; VALDE-NOWAK, 1977). Similarly, although on a smaller scale in other parts of Poland, radiolarites were relatively late to be classified as potential sources of raw materials obtained during the Stone Age. The research focused on the area of Upper Silesian 'Gliwice radiolarite' (GINTER, 1973, 1974; FOLTYN *et al.*, 2009) and in the Flish Carpathians in south-eastern Poland (so-called flysch radiolarite: RYDLEWSKI, 1989a-b; VALDE-NOWAK, 2009; VALDE-NOWAK *et al.*, 2014). Studies on the distribution of radiolarite for individual regions and periods of the Stone Age were made (e.g. SCHILD, 1975, p. 267-270; KOZŁOWSKI *et al.*, 1981; CYREK, 1983; RYDLEWSKI, 1989a-b; SULGOSTOWSKA, 2005). A detailed presentation of the sites located at and around radiolarite outcrops has already been proposed (KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989a-b, 2009; FOLTYN *et al.*, 2009), but their numbers are still increasing.

The exact division into varieties was made at the same time for samples from radiolarite outcrops in the Polish part of PKB, taking into account genetic and macroscopic features (groups I/1 - II/3, VALDE-NOWAK, 1979; KOZŁOWSKI *et al.*, 1981), red, green and manganese radiolarites, including division of PKB into lithostratigraphic units and formations (BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989b), as well as for Slovak radiolarites derived from abundant high-quality raw materials in the Vlara River Valley of the White Carpathians (groups 1-8, CHEBEN & ILLÁŠOVÁ, 1997) and Hungarian sources (ELEKES *et al.*, 2000; BIRÓ, 2002). Among these deposits are all colour variants. Attempts to isolate the characteristics of radiolarites indicating the origin of particular outcrops within the Carpathian Arc (CHEBEN & ILLÁŠOVÁ, 1997; KOZŁOWSKI *et al.*, 1981; CHEBEN & CHEBEN, 2009), as well as distinguishing Carpathian and Alpine resources (BRANDL *et al.*, 2013), whether from other regions (e.g. ELEKES *et al.*, 2000) have been made several times. Some of them have yielded positive results (e.g. BRANDL *et al.*, 2013).

4. LOCALISATION AND CHARACTERISATION OF THE PIENINY KLIPPEN BELT (PKB) IN POLAND

The Pieniny Klippen Belt is the Mesozoic and Palaeozoic rock formation that runs among the Tertiary domain (KOZŁOWSKI *et al.*, 1981). The Polish part of this formation is well recognised (BIRKENMAJER, 1979). The radiolarite deposits found therein are equally well documented


100
0
100
200
300
400 km
WESTERN BESKIDY MOUNTAINS
Orawa-Nowy Targ Basin
PIENINY
KLIPPEN BELT
Spisko-Gubałowskie Foothills
Sub-Tatra Through
TATRA MOUNTAINS
7.5
0
7.5
15
22.5
30 km

and described (KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989a-b). In Poland PKB is visible on the surface in the area between Stare Bystre and the Małe Pieniny Mountains (Fig. 1). In the west the belt is covered by younger sediments. It usually consists of units (succession, series) of rocks formed in the area of sedimentation. The shallowest is the Czorsztyńska unit. Czertezicka and Niedzica are the transitional series, and the Braniska and Pieniny units are the deepest ones. Other units are located in Slovakia and nearby regions (BIRKENMAJER, 1979).

Similarly made deposits compose so-called lithostratigraphic formations. Formations with radiolarite-bearing layers are the Sokolica, Czajakowa and Jarmuta formations. Some formations are divided into smaller units (BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981).

According to previous research (BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989a-b, 2009), the Polish section of the PKB was divided into three parts: west from Stare Bystre to Krempachy, central part of Pieniny Spiskie from Białka and Branisko to Niedzica and western part from Czorsztyn through Sromowce Średnie to the Flaki massif and Małe Pieniny Mountains (Fig. 1).

Radiolarites are also found in many parts of the PKB as secondary deposits, in valleys streams, rivers and showers. They also occur on Orava (western part of Podhale) in the form of erratic boulders, although the PKB is covered here by younger sediments.

The outcrops of the western groups are located between the Stare Bystre and Szaflary. Radiolarites occur in the slopes of easily accessible hills and well visible peaks, such as the Red Rock in Stare Bystre or Raniszberg in Maruszyna/Szaflary, as well as in the streams and other natural unveilings (Fig. 2). They are also present in secondary position in stream valleys, e.g. Wielki Rogoźnik or smaller streams, but in the form of rare and relatively small nodules. Another situation is the Biały Dunajec Valley, where radiolarites occur in its steep banks and in all parts of the river valley in Szaflary and Biały Dunajec villages. These are good quality and easily accessible materials. Most of the above-mentioned outcrops are rich in red and green variants, but the manganese-type is present too. A steel-grey variant is well represented in the western slope of Szaflary-Bór Hill (Fig. 2).

A very important zone in the central part of PKB is the Branisko-Hombark Massif and its neighbouring areas. This is an elongated hill with mild slopes, where the primary outcrops of good quality red variant radiolarite are probably located. The better source for selected good quality raw materials is the fluvioglacial fan of Branisko and the valley of the Branisko stream. These are rich and valuable resources that were certainly used during the Stone Age. Radiolarites of few variants occur also near the Obłazowa Cave and Kramnica Mount, near the Krempachy village. They occur mainly in streams and on the natural unveilings. Comparable to Branisko source are the Falsztyn radiolarites, that are also of very good quality and its primary and secondary outcrops are rich in raw materials (Fig. 3). Nearby are the radiolarites of Niedzica - Castle Hill and neighbouring outcrops that are recently covered by the waters of an artificial lake made in the small Dunajec river turn.

The eastern group is the richest in radiolarite outcrops but it is also the most mountainous region of all those mentioned above. There are outcrops in the rocky mountains, such as Flaki, Three Crowns (Fig. 3), Sokolica Jarmuta or the valleys and streams such as Harcygrund, Grajcarek (Fig. 1). This region is lesser accessible

Fig. 1 – (opposite page) Location of the Pieniny Klippen Belt and the main radiolarite outcrops (after BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989b, 2009, simplified).
1: Stare Bystre; 2-3: Maruszyna; 4-7: Szaflary; 8: Branisko; 9 and 11: Niedzica; 10: Falsztyn – Kosarzyska; 12: Harcygrund Valley; 13: Kapuśnica Mountain; 14: Flaki Massif; 15: Rabsztyn; 16: Żłobiny – Biała Skała; 17: Trzy Korony; 18: Kurnikowa Rock; 19: Czertezik; 20: Sokolica; 21-24: Szczawnica ; 25: Jarmuta; 26: Dolina potoku Krupianka; 27: Jaworki; 28: Homole.

than the above mentioned, but the richest in all radiolarite variants - red, green, steel-grey or manganese. In these regions the greatest Palaeolithic workshops processed radiolarites are known from all of the PKB sources (RYDLEWSKI & VALDE-NOWAK, 1977, 1978b-c, 1982c, 1982d).

Most of the above described outcrops could be possible sources for raw material for Stone Age communities. There are good quality and accessible radiolarites, certainly known by these societies.

5. THE POSSIBILITIES OF ACQUISITION OF RADIOLARITES IN PKB

In the Polish part of Pieniny Klippen Belt there is no direct evidence for mining methods of radiolarite exploitation, but examples are known from the neighbouring areas. In the PKB range numerous workshops processing local radiolarite were discovered. The oldest mining tools in Europe also originated from this region (see below). It is therefore very possible that radiolarite was also exploited in this area through

Fig. 2 – Examples of radiolarite outcrops and samples of raw material from western group of PKB; 1-3, 6, 9: Maruszyna; 4, 5, 7, 8: Szaflary.

mining, as suggested for comparable contexts e.g. in Italy (MAGGI *et al.*, 1995).

Primary radiolarite deposits were exploited by mining methods during the Neolithic and Aeneolithic, as indicated by the examples from Austria (Mauer-Antonshöhe, BRANDL *et al.*, 2013, 2015), Slovakia (Vrsatecke Podhradie, Bolesov-Tri Kopce and other, CHEBEN & CHEBEN, 2015), Hungary (Tata - Kálvariadomb, Bakonycsernye - Tűzköveshegy and others, ELEKES *et al.*, 2000) or in Italy (MAGGI *et al.*, 1995).

An interesting example of the direct use of radiolarite from the rock wall is the Neolithic mine complex situated in the Lagorara Valley in the Apennines (Italy). They were extracted with hard tools directly from the high vertical rocky

Fig. 3 – Examples of radiolarite outcrops and samples of raw material from central and eastern group of PKB. 1, 4: Falsztyn; 2-3, 5-6: Branisko; 7-9: Flaki Massif; 10: View on central part of PKB from Cisowa Rock. In the foreground – Obłazowa and Kramnica Rocks; 11: Branisko Hill; 12: Flaki Massif; 13: Trzy Korony Mount).

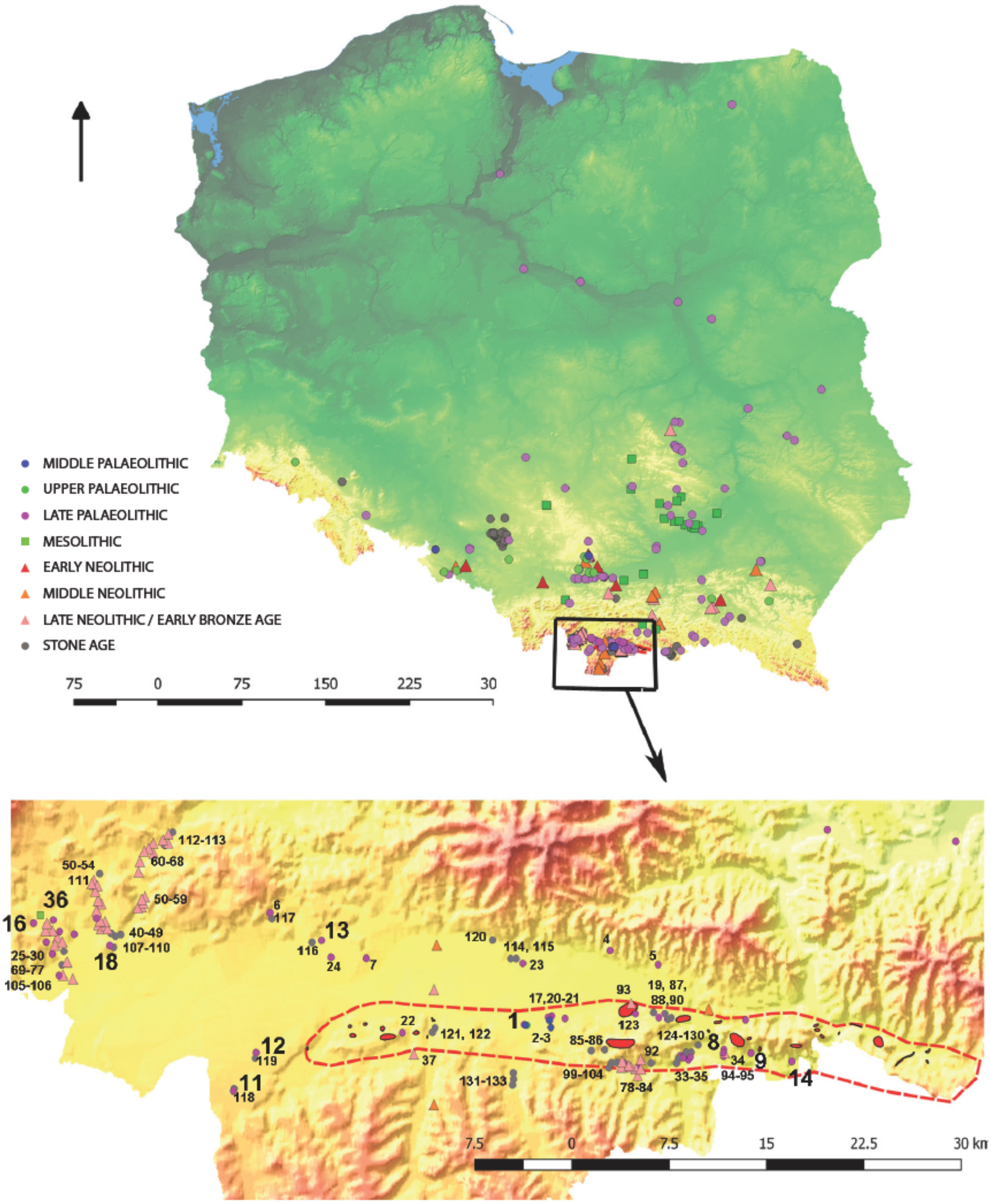


Fig. 4 – Upper part: Location of the Stone Age sites, where the presence of radiolarite artefacts has been confirmed in the territory of Poland; Lower part: Main sites located in the range of PKB or its vicinity. 1: Nowa Biała site 2, Obłazowa Cave; 2-3: Krempachy; 4: Szlembark; 5: Maniowy; 6, 117: Odrowąż; 7: Krauszów; 8: Sromowce Wyżne 'site 2'; 9: Sromowce Wyżne-Kąty; 10: (8 on the map): Sromowce Wyżne, 'site 8'; 11: Koniówka site 1; 12: Podczerwone site 1; 13: Dział, site 1; 14: Sromowce Niżne, site 1; 15 (1 on the map): Nowa Biała, 'site 1'; 16: Lipnica Wielka, 'site 2'; 17: Krempachy, 'site 1'; 18: Jabłonka, 'site 22'; 19, 87-88, 90: Falsztyn; 20-21: Krempachy; 22, 89, 91: Maruszyna; 23: Łopuszna; 24: Długopole; 25-30: Lipnica Wielka; 31, 107-110: Jabłonka; 33-35, 124-130: Niedzica; 36: Lipnica Wielka, 'site 8'; 37: Bańska; 38, 123: Frydman; 39, 94-95: Sromowce Wyżne; 40-49: Jabłonka; 50-54, 111: Zubrzyca; 55-59: Orawka; 60-68: Podwilk; 69-77, 105-106: Lipnica Wielka; 78-84, 99-104: Łapsze Niżne; 85-86: Dursztyn; 92: Niedzica; 93: Frydman; 96-97, 112-113: Podwilk; 114-115: Ostrowsko; 116: Dział; 118: Koniówka; 119: Podczerwone; 120: Waksmund; 121-122: Szaflary; 131-133: Białka Tatrzańska.

slope. Further processing was made at the foot of the wall. Traces of all stages of this activity have been preserved until recent times (MAGGI *et al.,* 1995).

In Western Slovakia, mining activity shows a different character. These were pits or deep shafts sunk in the surface, such as Vrsatecke Podhradie, Krivoklat, Bolesov - Tri Kopce. As in Valle Lagorara, initial processing was conducted in the mining area (CHEBEN & ILLÁŠOVÁ, 1997; CHEBEN & CHEBEN, 2009).

In the mine located in the Mauer - Antonshöhe hill in Vienna, Austria, deep shafts with small galleries were found (TRNKA, 2011). In Hungary, where radiolarite was one of the basic raw materials, numerous mines and processing workshops were discovered. One of the most important mines is Szentgál - Tüzköveshegy - 'flint hill' in the Bakony Mountains with mining pits and shafts (BIRÓ, 1995; ELEKES *et al.*, 2000). This raw material was probably already worked in the Middle and Late Palaeolithic, as evidenced by its presence in sites from this period. However, there are no indicators of its mining before the Neolithic (TAKÁS-BIRÓ, 1986, BIRÓ & REGENYE, 2007). In the Bakony Mountains, there are several other radiolarite outcrops that were exploited in the Stone Age. Bakonycsernye - Tüzkövesarow or Hárskut - Édesvismajor, Veszprém, but archaeological research was not carried out (BÁCSKAY, 1995; BIRÓ & REGENYE, 2007). In the Gereccse Mountains, the remains of numerous mines were also found. Both at the Dunaszentmiklós - Hosszuvontató and at Lábatlan - Margiltetö, or in Lábatlan - Pisznicetetö (Komárom district), exploitation made directly from the rock was confirmed. Radiolarites were collected most likely from the exposed part of the deposit (as in the Apennines; BÁCSKAY, 1995).

Within the range of the radiolarite outcrops in PKB one Middle Palaeolithic site Nowa Biała 2 (Obłazowa Cave) has been recognised (Fig. 4). The composition of the inventory in the settlement levels of the Mousterian culture (XXb, XVII, XVI, XV, XIII) and the Micoquian level (XVIIIb), confirms the intensive use of local varieties of radiolarite, especially the red ones (MADEYSKA *et al.*, 2002; VALDE-NOWAK, 2010; VALDE-NOWAK & NADACHOWSKI, 2013; CIEŚLA & VALDE-NOWAK, 2014). Higher in the stratigraphy, mostly in the Upper Palaeolithic levels of the cave in Obłazowa, the raw material of individual inventories is more diversified, but the products made of local radiolarites are predominant. In Layer XI (Szeletian settlement level), the majority of the material was made of red radiolarite (VALDE-NOWAK *et al.*, 2003). In the Layer VIII of the cave in Obłazowa (Gravettian - Pavlovian), green radiolarite slightly overlaps with other variants. From this layer came two antler wedges, classified as mining girders, one of which ornamented (VALDE-NOWAK *et al.*, 2003, p. 56). They are believed to be the oldest mining tools from Poland. Another antler tool was also discovered as a stray find probably at the Kłodne site in the Pieniny area itself, but this hoe-shaped antler artefact is not available for analysis (a Neolithic age cannot be excluded; ŻAKI, 1958).

The largest number of PKB sites on which radiolarite artefacts are recorded is associated with Late Palaeolithic, starting with the Magdalenian culture, with which the largest processing workshops in this area are connected. In the eastern part of the PKB, the radiolarite that was processed was green, with a small share of the other varieties (Sromowce Wyżne - Kąty; RYDLEWSKI & VALDE-NOWAK, 1982c-d; RYDLEWSKI, 1989a-b, 2009; VALDE-NOWAK *et al.*, 2005; Sromowce Wyżne, st. 8; DROBNIEWICZ *et al.*, 1997). It is believed that radiolarites were sourced directly from its slopes, and supplemented by pieces of river nodules. There are also numerous Magdalenian sites where the local red variety dominates (Koniówka st. 1, Podczerwone st. 1; RYDLEWSKI & VALDE-NOWAK, 1981a, d, e; RYDLEWSKI, 1989a-b; VALDE-NOWAK, 1991).

The Arch Backed Piece technocomplex in the area of PKB covers two sites: Sromowce Niżne 1 (RYDLEWSKI & VALDE-NOWAK, 1977, 1978b; RYDLEWSKI, 1989b) and Nowa Biała 1 (VALDE-NOWAK, 1986, 1987; VALDE-NOWAK & KRASZEWSKA, 2014). In Sromowce Niżne, the green and grey radiolarites are the most common while on the site of Nowa Biała 1 the red variety dominates (VALDE-NOWAK, 1987; RYDLEWSKI, 1989b). This is similar to the Magdalenian sites situated within the PKB deposits, the situation is consistent with the distance from individual sites to the large outcrops in which other variants predominate (Fig. 4).

There are several larger sites of Tanged Point Cultures in the vicinity of the PKB (like Lipnica Wielka 2, Dział I/85). These sites, however, are not located in the direct range of the primary sources of PKB radiolarites, which may explain the minor presence of this material in their inventories (RYDLEWSKI & VALDE-NOWAK, 1978a, 1978c, 1979a, 1982a-d; RYDLEWSKI, 1985). Other sites from this period are the remnants of short-term camps, especially in the eastern part of the PPS, where all varieties of radiolarites occurred (Krempachy, Fig. 4; RYDLEWSKI, 1989b, 1990).

The Mesolithic settlements within the Pieniny radiolarite is limited to several settlement points and a larger camp and workshop in Lipnica Wielka 8, located a dozen or so kilometres to the west of the outcrop. Except for the vast majority of Jurassic flints, the red and green radiolarite varieties were also processed there (RYDLEWSKI, 1989a-b, 2006; Fig. 4).

There are no sites dated to the Early Neolithic where local radiolarite was used, but there are numerous settlements from the Neolithic and Early Bronze Age located in the vicinity of the Pieniny deposits: the Biały Dunajec, Frydman as well as tributaries of the Czarna Orawa in the west (Fig. 4; VALDE-NOWAK, 1980; RYDLEWSKI & VALDE-NOWAK, 1981h; KOPACZ & VALDE-NOWAK, 1987; RYDLEWSKI, 1989a-b; KOPACZ, 2001).

6. DISTRIBUTION OF RADIOLARITES AND THE PROBLEM OF THE IDENTIFICATION OF THEIR PROVENANCE

Evaluating the distribution of radiolarite is a complex issue. Primary and secondary radiolarite outcrops are located in Slovakia, Austria, Hungary, Czech Republic and in many other regions. Most of the outcrops of good quality radiolarite in Poland are to be found in the Pieniny Klippen Belt. The problem of the identification of the local, specific source outcrop of the lithic material is still a work in progress and is not easy to solve.

Apart from the distribution of radiolarites originating from the southern and western parts of Europe, primarily PKB radiolarite (VALDE-NOWAK, 1979; KOZŁOWSKI *et al.*, 1981), 'Gliwice' (FOLTYN *et al.*, 2009) and Flysh radiolarite (VALDE-NOWAK, 2009) were the subject of distribution during the Stone Age. In Poland there are currently over 300 sites from all periods of the Stone Age, where radiolarite artefacts have been recorded (Fig. 4).

The oldest Middle Palaeolithic inventories with imported radiolarites come from the Ciemna Cave (Cracow-Czestochowa Upland). It is a hand axe connected with the Micoquian cultural level made of the steel-grey radiolarite and the Levallois point from the level containing the Mousterian components (SOBCZYK & VALDE-NOWAK, 2012, p. 49-50). Another specimen from this period also probably made of radiolarite is the tool from the site no 2 in Lisięcice in Głubczyce in Silesia (WIŚNIEWSKI, 2006, p. 218). So far these are the only known sites in Poland of such a distant chronology, where the presence of radiolarite can be confirmed.

Among younger inventories, radiolarites were relatively abundant among assemblages of the sites concentrated in and around Cracow and Silesia. They were present in the large Szeletian camps (Kraków Zwierzyniec, Lubotyn st. 11; SAWICKI, 1949; KOWALSKI & KOZŁOWSKI, 1959; KOZŁOWSKI *et al.*, 1981; KOZŁOWSKI, 2006; MAŃKA, 2006; BOBAK & POLTOWICZ-BOBAK, 2010) as well as Jerzmanowice culture sites (Nietoperzowa Cave in Jerzmanowice, Mamutowa Cave; CHMIELEWSKI, 1975).

At Gravettian sites occurring outside the outcrops, radiolarite was noted in the inventory of rich sites, such as Cracow Spadzista in Małopolska, Cyprzanów I or Marzankowice in Silesia (DROBIEWICZ *et al.*, 1976; KOWALSKI & KOZŁOWSKI, 1959; KOZŁOWSKI *et al.*, 1981). In the Upper Palaeolithic, Flysch radiolarite was used, as indicated by the inventory of the Epigravettian site of Ujazd in Podkarpacie, where the import of the red radiolarite from PKB was also confirmed (VALDE-NOWAK, 2006).

The most common variant among the imports of radiolarites during Magdalenian culture is red, occurring in the Maszycka cave, Wilczyce and other great and important sites (KOZŁOWSKI *et al.*, 1981; SULGOSTOWSKA, 2005; GINTER *et al.*, 2007; WIŚNIEWSKI, 2008). As researches indicate, the red radiolarite from Dzierżyslaw comes from the Moravian and Slovak outcrops (GINTER *et al.*, 2002, p. 120, 2007). The yellowish variety radiolarite, previously unknown from older Palaeolithic sites, has appeared in several Magdalenian culture sites, including the Maszycka Caves (KOZŁOWSKI, 1963; KOZŁOWSKI *et al.*, 1981; WIŚNIEWSKI, 2008; SULGOSTOWSKA, 2005). It was originally suggested that it was connected with Alpine deposits. The hypothesis of an Upper Silesian Gliwice origin was recently proposed (FOLTYN *et al.*, 2009). Among the Magdalenian inventories located outside the radiolarite outcrops no production from the green variety of radiolarite has been recorded so far (SOBKOWIAK-TABAKA, 2011); some researchers are therefore inclining towards the non-Polish south-western origins hypothesis. It is worth mentioning, however, that the red variety of the radiolarite occurs in all known outcrops, and on the Polish territory its exploitation can be also confirmed.

Among imported artefacts of Arch Backed Piece sites, mainly red radiolarites, usually appear individually. The exception is the site of Nowy Młyn III/77 (Rydno) (SCHILD *et al.*, 2011; SULGOSTOWSKA, 2005). Single specimens of the yellow-red variety were recorded at Wola Boksicka/Bokszycka (KOZŁOWSKI *et al.*, 1981; SULGOSTOWSKA, 2005) and in Pawłów on the Sandomierz upland (LIBERA *et al.*, 2008).

Most of the sites where the imported radiolarite artefacts were recorded are associated with Tanged Point Cultures settlements, which also cover the widest geographical range. Individual specimens are found in the sites located far away from the outcrops, located in Mazovia (Gulin, Marki - Warszawa, Mińsk Mazowiecki, LIBERA, 1998; SULGOSTOWSKA, 2005, p. 194) and even in the northern part of Poland (JURZYSTA, 2010). The greatest concentrations, however, are located in the south of Poland, on the Cracow-Czestochowa Upland, where they have been recorded since the 1930s on sites in Borek Fałęcki, Cracow-Kobierzyn, Cracow-Tyniec (Bagno) or Zakrzów (KOWALSKI & KOZŁOWSKI, 1959), as well as many others, regularly increasing this inventory (e.g. STEFAŃSKI & WILCZYŃSKI, 2012). Radiolarite is also commonly found in the site inventories from that period on the Sandomierz and Lublin Uplands (south eastern part of Poland). The most numerous examples come from Chwalibogowice, Wilkowa or Opatowiec (SCHILD, 1975; KOZŁOWSKI *et al.*, 1981; LIBERA, 1998; SULGOSTOWSKA, 2005). Similarly, although on a smaller scale, this raw material was used in sites located in the western and south-western parts of Poland (Janów, Wąsosz Górny, Byczeń; GINTER, 1963; SCHILD, 1975; SOBKOWIAK-TABAKA, 2011; SULGOSTOWSKA, 2005). In the Tanged Point Culture assemblages the radiolarite was also obtained from other Polish outcrops. In Silesia (Gliwice) it can be identified in workshops and camp-sites in Zabrze - Mikulczyce or Gliwice - Sobiszowice (GINTER, 1974; FOLTYN *et al.*, 2009). The radiolarite was also used in the Flysh Carpathians, which is confirmed by the raw material inventory of several sites (Żegiestów, Czermna st. 6, Żeglce st. 10, Nienaszow st. 6, Trzebowisko st. 11; RYDLEWSKI, 1989a-b, 1990; SULGOSTOWSKA, 2005; WAWRZCZAK, 2010).

In the early phase of the Mesolithic, there were few sites with radiolarite imports, but in the later phase it was distributed on a larger scale (CYREK, 1983, p. 111-112; SULGOSTOWSKA, 2005). The Early Mesolithic can be combined with one of the sites located on the Sandomierz Gorge (Chwalibogowice, Dziesławice, Borzym, Żerniki; SULGOSTOWSKA, 2005). In the Late Mesolithic, in the Sandomierz Upland, in the Malopolska Upland and in the Carpathian Foothills, this material appears more frequently, albeit often individually (Dąbrówka, Borki Radkowice, Borzym, Grabowa, Jamno, Janina, Lubania, Połaniec, Ruszcza, Zrębin; VALDE-NOWAK, 1979; KOZŁOWSKI *et al.*, 1981, RYDLEWSKI, 1989b; SULGOSTOWSKA, 2005). Exceptional are the sites in Strzelce and Brzozówka, where they were more numerous (SULGOSTOWSKA, 2005), the Mesolithic sites in Mucharz in the Skawa River basin (RYDLEWSKI & VALDE-NOWAK, 1979a-c; VALDE-NOWAK & TARASIŃSKI, 2010) as well as Luta type trapezium made of red-green radiolarite found in Sułkowice (Gościbia) in Komornica cultural context (VALDE-NOWAK, 2012). In the area of the 'Gliwice' radiolarite deposits in the

Mesolithic inventory of the sites in Dzierżno (sites no 3, 5, 6), there are workshops of red local variety (GINTER, 1973; KOZŁOWSKI *et al.*, 1981; FOLTYN *et al.*, 2009).

In the Neolithic (Aeneolithic) the presence of artefacts made of red radiolarites was reported but they are relatively rare, in contrast with the nearby mining areas in Slovakia, Austria or Hungary. Imports focus on Podkarpackie (e.g. Rzeszów Piastów, KOZŁOWSKI & KOZŁOWSKI, 1977; KOZŁOWSKI *et al.*, 1981; BALCER, 1983), in Silesia (Pietrowice Wielkie, BUKOWSKA-GEDIGOWA, 1980) and in Małopolska (Bolechów, Złota and Czchów; MADEJ & VALDE-NOWAK, 2001; CZEKAJ-ZASTAWNY, 2008; Nowy Sącz - Biegonice, CABALSKA, 1967; KOZŁOWSKI *et al.*, 1981; Jawczyce - ZOLL-ADAMIKOWA & NIŻNIK, 1963), with subsequent Aeneolithic groups such as the Baden culture in the Cracow-Czestochowa caves (ROOK, 1980, p. 52) and Cracow-Witkowice II (Cracow, Poland; RYDLEWSKI & VALDE-NOWAK, 1981g), or the Funnel Beaker Culture – Racibórz-Studzienna (KOZŁOWSKI *et al.*, 1981), Sieklówka in Podkarpacie (GANCARSKI, 1989).

In the Late Neolithic and Bronze Age, radiolarites are present on sites in Małopolska and Podkarpacie (WŁODARCZAK, 2006; ZOLL-ADAMIKOWA & NIŻNIK, 1963). The most abundant collection comes from the Maszkowice, located on the Dunajec River, at a slight distance from the Pieniny and Flysch resources. The share of radiolarites accounted for over 60 % of the inventory. All radiolarite variants occurring in PKB (red, green, steel-grey) were used. A significant percentage of these are sites connected with the Epicorded Ware Culture of the Carpathian region, where among the inventories most often are locally produced artefacts (KOPACZ & VALDE-NOWAK, 1987; VALDE-NOWAK, 1989).

In the area of the Gliwice radiolarite, many of the sites from surface and excavation studies do not have precise dating either. They probably are the remnants of local radiolarite processing workshops (FOLTYN *et al.*, 2009). Large groups of individual artefacts were also found at sites located along the main Carpathian watercourses - the Dunajec and Poprad Valleys (TUNIA, 1977). A large number of these sites indicate a significant impact of radiolarite, especially in some regions, which are usually associated with local processing, but also show its significance in particular periods of the Stone Age.

7. DISCUSSION

Radiolarites, as an extremely colourful, varied resource, were certainly of interest to the Stone Age communities, both for their technological and aesthetic qualities. Its symbolic meaning, especially the red variety, was already emphasised in the literature (SULGOSTOWSKA, 2005; STEFAŃSKI & WILCZYŃSKI, 2012). Neighbouring areas are known for examples of the production of prestigious jewellery (from the Szentgal radiolarite, cf. TAKÁS-BIRÓ, 1986), or selected blades made of this raw material stored as treasures (Zabrze-Mikulczyce, FOLTYN *et al.,* 2009), as well as the production of distinctive 'special' tools - leaf points in transitional cultures of the Upper Palaeolithic or small leaf points in Tanged Point Cultures. Symbolic caches can also be seen in some mine shafts in Mauer-Antonshöhe (BRANDL & TRNKA, 2015). The technical characteristics of the raw material also had to be satisfactory. This is evidenced by the use of radiolarites by communities with different technological traditions.

The Pieniny Klippen Belt is a geological unit particularly rich in great quality radiolarites that were used during the Stone Age. Evidence of its distribution should be considered as a strong possibility, especially among Late Palaeolithic inventories on the territory of Poland.

As for now in Poland there are no direct traces of the exploitation of rock walls or underground mining. As observed in neighbouring areas, such complicated exploitation systems are characteristic of the Neolithic, but are not known for the Palaeolithic or Mesolithic. In PKB or any other outcrop in Poland, there are just a few traces of Neolithic or Aeneolithic activity. Similarly, radiolarite as an imported material did not acquire the same importance in the Polish Neolithic as to the neighbouring areas, or as to its success in the Polish earlier Stone Age. It is notable that Polish raw materials, such as Jurassic flints or chocolate flints, had an important significance in Slovakia, and in areas located over a dozen kilometres from the PKB outcrops, e.g. in Velky Slavkov. A similar situation can be found in Moravia and in Hungary, which may suggest that the radiolarites from these outcrops could also have been imported to the Polish territory.

As already mentioned, the problem of identifying the primary sources of radiolarite artefacts has already been widely discussed. New methods of exploring these commodities are being introduced, yielding a number of positive results (see CHEBEN & ILLÁŠOVÁ, 1997, p. 61; BRANDL *et al.*, 2013) which in the future will open the possibility of making even more precise studies on the radiolarite use from Polish outcrops.

8. CONCLUSION

In conclusion we may say that the above data indicates that the radiolarite played an important role in the Stone Age in the Polish territory that goes beyond the boundaries of its deposits, and even over a considerable distance. This raw material has been used extensively in the Palaeolithic, as evidenced by numerous processing workshops and settlement points related to the exploitation of deposits, as well as widely distributed. The oldest traces date back to the Middle Palaeolithic. The widest range of its propagation is towards the end of the period, and related to Tanged Point Cultures settlements, especially Mazovian. Radiolarite was also used in the Mesolithic, especially the later part of the period. In the Polish Early Neolithic and Aeneolithic, its lesser significance contrasts with neighbouring areas, where in Slovakia, Hungary or Austria, mining methods of exploitation played a key role (BIRÓ, 2002; BIRÓ *et al.*, 2007). Concentrations of sites with radiolarite assemblages occur at several points. Their highest density is in the area of occurrence of radiolarite deposits and their vicinity. Most imported radiolarites are found in the Sandomierska Valley and in the vicinity of Cracow, and later in Podkarpacie, in the basin of Poprad and Dunajec, in Upper Silesia, but imports could extend to a few hundred kilometres further. They appear in the northern regions of Poland, such as Mazovia or Kujawy, according to the principle of the 'Fall-off effect' (e.g. SULGOSTOWSKA, 2005).

The problem of primary sources of radiolarite artefacts in Poland is still open and studies in this subject need to be continued.

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Extraction of chert boudinage from the Lower-Middle Ordovician Ontelaunee Formation, Wallkill River Valley, Northwestern New Jersey-Southeastern New York

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Abstract

The authors examine the extent to which several episodes of tectonic deformation impact prehistoric chert quarry activity of the chert-bearing Ordovician Ontelaunee Formation. The paper discusses a variety of measureable outcrop and fabric characteristics that impact prospection, extraction and the resulting chain of operation. The results of our analysis indicate that quarrying of bedrock is not an expedient process, but involves considerable planning and orchestration within the seasonal round.

Keywords: bedrock quarries, Ontelaunee Formation, boudinage, tectonic deformation.

Résumé

Dans cet article, les auteurs examinent dans quelle mesure plusieurs épisodes de déformation tectonique affectent l'exploitation minière préhistorique de chert de la Formation ordovicienne d'Ontelaunee. L'article discute d'une grande variété de caractéristiques d'affleurement et de structures mesurables qui ont un impact sur la prospection, l'extraction et la chaîne opératoire qui en résulte. L'étude montre que l'extraction de la roche en place n'est pas une opération opportuniste, mais nécessite une très importante planification et orchestration dans le cadre du cycle saisonnier.

Mots-clés*: carrières du socle, Formation d'Ontelaunee, boudinage, déformation tectonique.*

1. Introduction

The Wallkill Valley in Sussex County, New Jersey and Orange County, New York is the home of greater than 800 prehistoric bedrock quarries cropping out within the Cambrian-Ordovician carbonates of the Great Valley Sequence (LAPORTA, 1994, 1996, 2005, 2009; LAPORTA *et al.*, 2017). Previous work has elucidated that the quarries are located in geological terrains determined by the tectonic deformation of the area (LAPORTA, 1994, 1996, 2005, 2009; LAPORTA *et al.*, 2017). The first-order structural features include normal fault, thrust ramp, back thrust, and plunging fold terrains mapped by LAPORTA (2009). Each geological entity displays finer scale tectonic deformation that impacts quarry prospection and extraction, as well as processing of the ore types targeted by prehistoric peoples. Second-order structures include folds accomodation, faults and petrofabric (cleavage, boudinage).

The authors examine the extent to which finer scale deformation impacts the mining experience by focusing on the Ontelaunee Formation and discussing the variety of measurable outcrop and fabric characteristics that impact prospection and extraction. The quarrying of bedrock is not an expedient process, but one that involves considerable planning and orchestration within a complex seasonal round. The more stratigraphically and structurally diverse rocks give rise to more elaborate, and information worthy, discernable prehistoric workings. The more foliated exposures challenge the ingenuity of ancient quarry workers; therefore the imprint of technological achievement is best documented at these quarries. The more complexly developed chert bearing rocks record more technologically sophisticated extraction, and a more elaborate chain of operation. Employing analogies of hand-operated bedrock quarry operations (LAPORTA, 2005), the authors can tentatively flesh out the various tasks and procedures required to prospect and develop a quarry and how this enterprise works in concert with annual subsistence activities.

2. Geological Setting

The Appalachian Mountains have suffered the amalgamation of at least two supercontinents, only to be torn asunder, creating three ocean basins (HATCHER *et al.*, 1989). The Grenville orogeny (T1) created the supercontinent Rodinia. In the study area, remnants of T1 are found in the Precambrian rocks comprising the Hudson and New Jersey Highlands. Continental rifting fractured Rodinia and created the Iapetos Ocean, which was followed by passive-margin development on the continent of Laurentia (proto-North America) as the ocean basin underwent seafloor spreading. The passive margin sequence is represented by the Cambrian-Ordovician chert-bearing carbonates housing the prehistoric quarries under examination; namely the Leithsville, Limeport, Upper Allentown, Stonehenge, Rickenbach, Epler and Ontelaunee formations (LAPORTA, 1994, 1996, 2009; LAPORTA *et al.*, 2017). Iapetos sea-floor spreading came to a close with attempted subduction of Laurentia beneath the Iapetos ocean floor (HATCHER *et al.*, 1989). Assembly of island arcs and microcontinents from the overriding Iapetos plate marked the Taconic Orogeny (T2). T2 deformation of the Cambrian-Ordovician carbonates in the Wallkill Valley is represented primarily by folds (F2) (LAPORTA, 2009; LAPORTA *et al.*, 2017). In the Wallkill Valley, the Crooked Swamp Synclinorium (F2) is the major Taconic feature (LAPORTA, 2009). F2 deforms and folds the entire Cambrian-Ordovician succession; with the up-plunge termination of the synclinorium exposed in the Rickenbach, Epler and Ontelaunee formations. Smaller scale folds ($F2_1$) within F2 are interpreted as accommodation structures associated with deformation and thrust faulting (LAPORTA, 2009; LAPORTA *et al.*, 2017). Prehistoric quarries discussed in this paper are located in this folded and faulted terrain; this plexus of structures determines the quarries' challenges. The synclinorium (F2), and folds within it ($F2_1$), shifts the trend of the raw material being quarried; rendering prospection of these ore targets exceedingly complicated (LAPORTA *et al.*, 2017). Three types of Taconic petrofabric, in the form of boudinage ($B2_1$, $B2_2$, $B2_3$), increase the number of discontinuities within the raw materials, directly impacting extraction, flaking, chain of operation (LAPORTA *et al.*, 2017).

The Acadian Orogeny (T3) was active for approximately 50 million years, during the Silurian and Early Devonian (HATCHER *et al.*, 1989). T3 involved a number of collisions between proto-North America and off-shore microcontinents, as well as the continent of proto-Africa. T3 resulted in the creation of the Acadian Mountains (HATCHER *et al.*, 1989). The identification of Acadian structures in the Wallkill is uncertain due to erosion of Silurian and Devonian rocks. However, the presence of Middle Devonian Schunemunk Conglomerate to the east of the Wallkill serves as undeniable evidence that the Acadian occurred in this region (LAPORTA, 2009).

The Alleghanian Orogeny (T4) spanned 65 Ma, during the Carboniferous (HATCHER *et al.*, 1989). Unlike T2 and T3, which primarily involved the collision of volcanic arcs and microcontinents, T4 involved continental-continental collision of Africa with North America. This collision formed the supercontinent Pangaea and caused widespread deformation along the eastern seaboard of North America (HATCHER *et al.*, 1989). Folding in the Wallkill Valley is not generally attributed to the Alleghanian. What folds do exist may be thrust-fault related folds in frontal imbricate zones (F4) (KING, 1964; BRYANT & REED, 1970; BUTLER, 1973; HATCHER, 1978). Late crenulation cleavage may be Alleghanian and of two forms; cleavage planes parallel to fold axial surfaces ($C4_1$), or cleavage-kink metamorphic foliation ($C4_2$) (BRYANT & REED, 1970; BUTLER, 1973). What is associated with T4 are southeast dipping thrust faults ($TF4_1$) that are responsible for offsetting of the Crooked

Swamp Synclinorium (F2) (LAPORTA, 2009). Taconic folding and fabric created challenges to extraction of raw materials. This complexity was increased significantly as a result of T4 thrusting and faulting. Additionally, back thrusts ($TF4_2$) in F2 provide yet a third consideration, especially when prospecting for raw materials.

2.1. Boudinage Development

Boudinage ($B2_1$, $B2_2$, $B2_3$) within the Ontelaunee Formation is the dominant petrofabric impacting prehistoric quarry extraction (LAPORTA, 2009). Boudinage consists of lenticular segments of a rock layer that have been pulled apart and flattened, in such a way, that the layer is segmented (DAVIS, 1984; HATCHER, 1995). The layer being segmented is stiffer than the enclosing material, and the degree of contrast in competence affects the shapes of the boudins: large contrast in the strength produces boudins with sharp edges; small contrast, boudins with rounded edges (DAVIS, 1984). If boudins exist in chert horizons, then the cherts are rheologically competent (stiff and rigid) materials, while the surrounding dolomite and limestone are incompetent and attenuated and flow between the rigid boudin blocks.

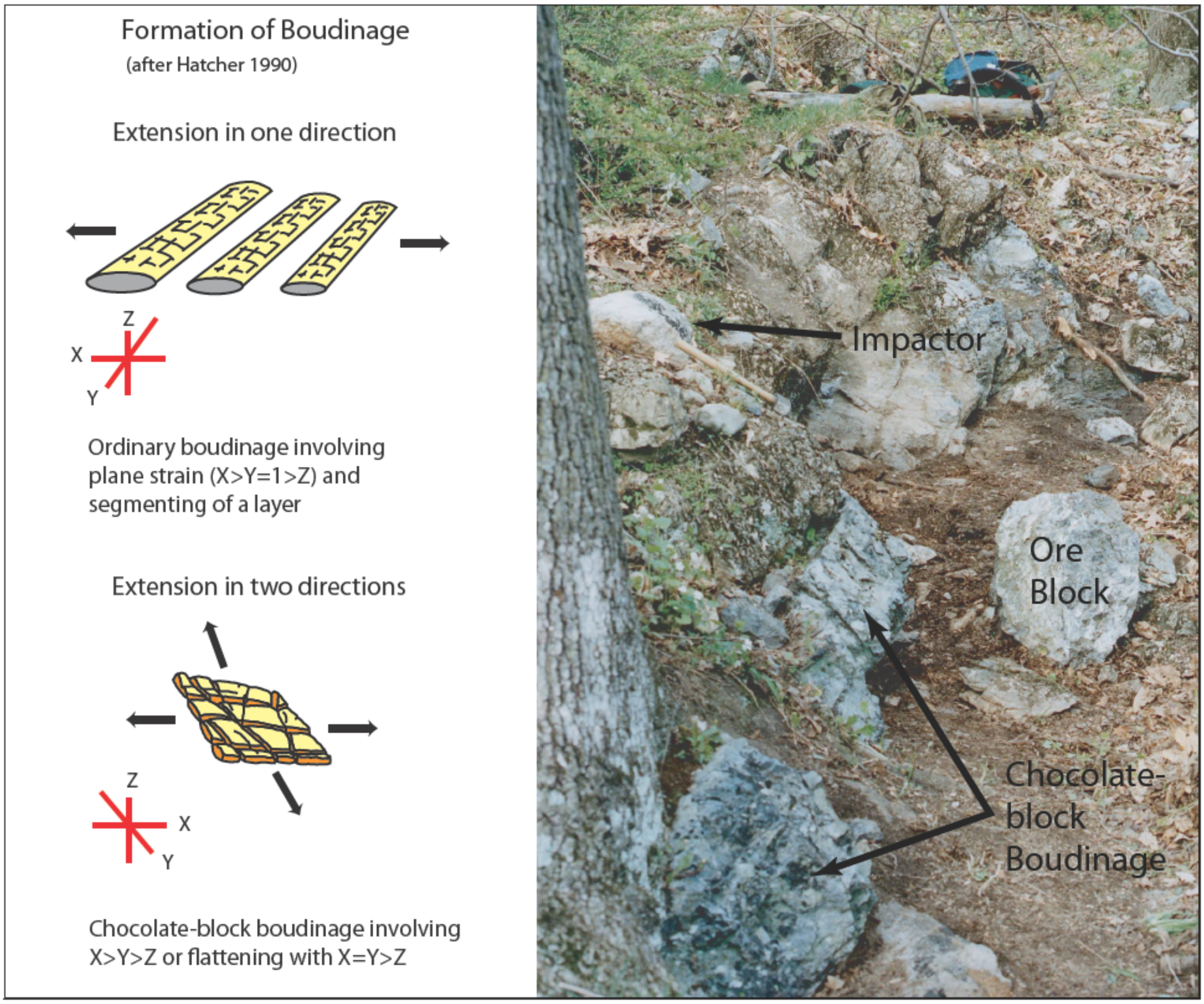

Fig. 1 – The left panel illustrates the effect of extension on one vs. two directions. The right panel reveals chocolate tablature boudinage in the Beaver Run Member of the Ontelaunee Formation. Note the quarried 'necks' between the boudins.

There are two general types of boudins (DAVIS, 1984; HATCHER, 1995; Fig. 1). Ordinary boudinage consists of segmented, sausage-shaped pieces of a single layer, in which the lenticular segments are parallel to one another and result from extension in a single direction. Chocolate-block/tablet boudinage has layer-parallel extension in two directions, resulting in boudinage that consists of a series of 3D blocks (Fig. 1).

Boudins may be completely separated from one another along 'boudin lines' or they may be connected by an attenuated neck in the layer (neck lines). Boudin neck lines are the focus of plug-and-feather methods during periods of quarry prospection and development, and are points of access during Zone 1 ore extraction (Fig. 2) (LAPORTA, 1996, 2005; LAPORTA *et al.*, 2017). Rock mechanics experiments have shown that the spacing of the fractures in the competent layer depends on the layer thickness and layer boundary properties (i.e., amount of friction between layers/amount of lubrication) (TWISS & MOORES, 1992). Few, if any, fractures appear if the boundary is well lubricated. Boudins may have a constant width and separation. This is critical for prehistoric mining, because if ore targets are boudinaged, the consistency in width and separation guides quarry development and ore extraction. Boudinage only occurs in strongly compressed areas of isoclinal folds (MARSHAK & MITRA, 1988) (such as $F2_1$ within the Ontelaunee Formation) (LAPORTA, 2009). If prehistoric miners recognized the correlation between isoclinally folded rocks and the presence of boudinage, which is possible as both are observable field characteristics, they may have developed an extraction strategy specifically for the boudinaged cherts of the Ontelaunee Formation (LAPORTA, 1996).

In the Wallkill Valley, boudinage is well developed within the Beaver Run (Fig. 1) and Harmonyvale members of the Ontelaunee Formation. Chert boudinage in the Ontelaunee are of importance because they are the primary ore target of prehistoric miners and serve as the focus of extraction in Zone 1 of the quarries. The Ontelaunee Formation contains second order isoclinal folds ($F2_1$) within the larger fold of the Crooked Swamp Synclinorium (F2), making it conducive

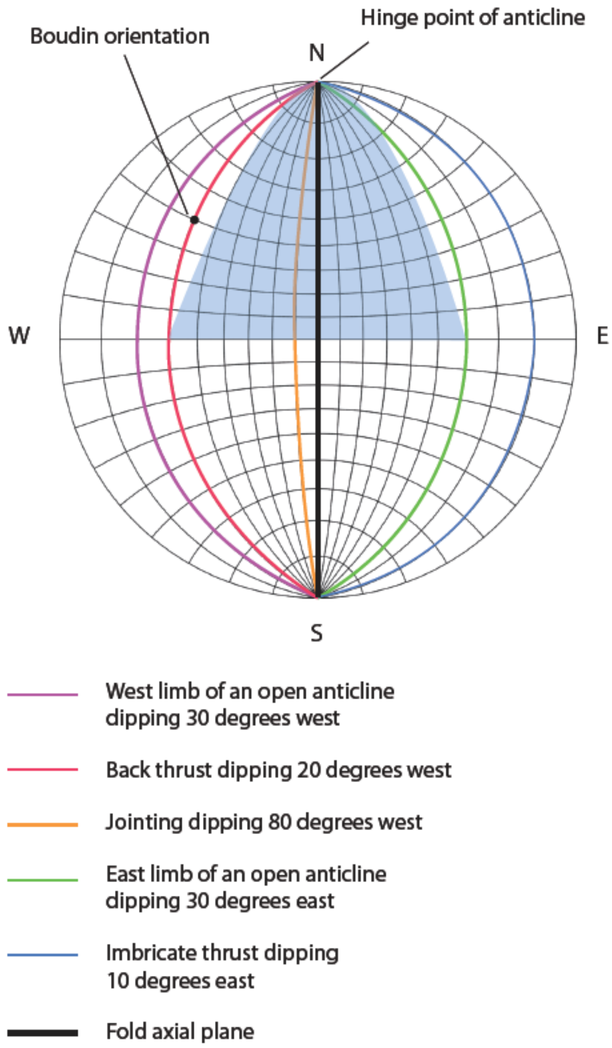

Fig. 2 – Stereographic projection is a tool geologists employ to plot three dimensional structures on two dimensional graphs. The intent is to show accurate angular and areal relationships between intersecting structures in space. On this stereographic projection, we have a generalized plotting of an open anticline with limbs dipping 60 degrees away from the fold axial surface. Also plotted on the stereonet are 3-D planes, represented as 2-D lines, intersecting the fold; such as boudins, back thrusts and imbricate thrusts. hese are representative structures that deform the Ontelaunee Formation of the Wallkill River Valley. While one of each type of structure is shown, it is important to realize that petrofabrics such as cleavage, joints, and boudinage are often penetrative throughout the entire rock. Such penetrative discontinuities in a raw material directly impact how it is mined and processed in the creation of a product.

to the development of a variety of boudinage structures ($B2_1$, $B2_2$, $B2_3$) and general strain fabric (LAPORTA, 2009). Ordinary boudinage is present in the Ontelaunee, but its rheological variation includes elliptical ($B2_1$) (fish eyed, articulate), block ($B2_2$), and elongate lenticular ($B2_3$) in shape.

The $B2_1$ boudins range from 20 to 30 ft in length, and as much as 11 ft in thickness. The boudinage pinch out into dolomites, and the thinnest part of the boudin neck contains reactivated anhydrite replaced by fibrous calcite (LAPORTA, 2009). Stratigraphically higher $B2_2$ bear sharp contacts on opposing sides of the limb, and joint-filling cements are both calcite and quartz (BRUECKNER *et al.*, 1987). The block boudins occur in as many as 40, 60, or 90 beds in succession, each intercalated with a thick dolomite. Individual block boudins are approximately six feet long by two feet thick (LAPORTA, 2009).

$B2_3$ occur within the transitional beds of the Harmonyvale Member. These elongate lenticular boudins are twenty times as wide as they are thick. They pass laterally into dolomitic limestones and limestones (LAPORTA, 2009). Therefore, the boudin dimensions prescribe the parameters of the chert bearing horizon as it crops out within Zone 1 of the quarry.

3. Environmental setting, prevailing conditions for quarry development: The continuance of process and inheritance of conditions (Schultz, 1985)

Geological mapping, archaeological excavation, mapping of prehistoric quarries in the Wallkill Valley has elucidated five zones of quarry development (Fig. 3) (LAPORTA, 1996, 2005; LAPORTA *et al.*, 2017). Zone 1 is the Zone of extraction, where the raw material is actively mined from the outcrop. Zone 2 is where ore milling occurs. Beneficiation of the dressed chert blocks occurs at Zone 3. Ore processing and washing are completed in Zone 4. Finally, refinement of the ore for its intended use occurs at Zone 5 workshops and factories (Fig. 3) (LAPORTA, 1996, 2005).

The parameters and primary tasks present within each Zone have been discussed in previous work (LAPORTA, 1996, 2005). The zones are discussed in this paper with the intent of emphasizing the role petrofabric plays in how extraction, milling, beneficiation, processing and refinement are carried out within a specific formation. Our intent is also to elucidate how labor intensive each process is within the chain of operation. While it has been shown that zones 1 through 5 can be elucidated through excavation at most bedrock quarries in Tectonic Cycle 1 of the Appalachians (LAPORTA *et al.*, 2017), we are introducing examples of intra- and inter-Zone variations in extraction processes resulting from petrofabric variations; or nuances occurring within the structural setting. However, the methods do exist which permit both the measurement, as well as the quantification, of such subtleties (Fig. 2) (MARSHAK & MITRA, 1988). The authors claim intra- and inter-Zone variations are common and predictable, primarily because tectonic deformation varies between geological formations and members within a region; and also within individual formation and member subdivisions. Strain response to tectonic stimuli varies as a result of lateral, and vertical, changes in rock rheology. Therefore within the same member, boudinage may be present in one specific location, but not in another. It is precisely due to this level of geological variability, that the authors have claimed that prehistoric bedrock quarries are initially a geological enterprise. Prehistoric miners possessed the cognitive ability (folk geology) to recognize geological factors that varied from location to location. Furthermore, prehistoric peoples addressed those variations by creating extraction methods and plans to fit the structural and stratigraphic nuances confronted in the rock record (BARKAI *et al.*, 2002, 2006; LAPORTA, 2005, 2009; LAPORTA *et al.*, 2017; SCHNEIDER & LAPORTA, 2008). Traditionally, archaeologists working on quarry-extraction technology do not possess the same level of intimacy with the rock outcrop, as did the indigenous peoples who quarried the rock. Therefore, what level of bias in modeling is precipitated from the repeated application of traditional archaeological field and laboratory methods, where extraction technology is concerned? The apparent cure for this bias is to embrace the quarry with geological reasoning, where necessary; as ultimately, cultural activity results in the modification of a naturally occurring mineral resource (LAPORTA, 2009).

As complex ore types require a sophisticated prehistoric understanding of the finer scale geology of a region, the need of input from the elders of the group is critical. Past quarry

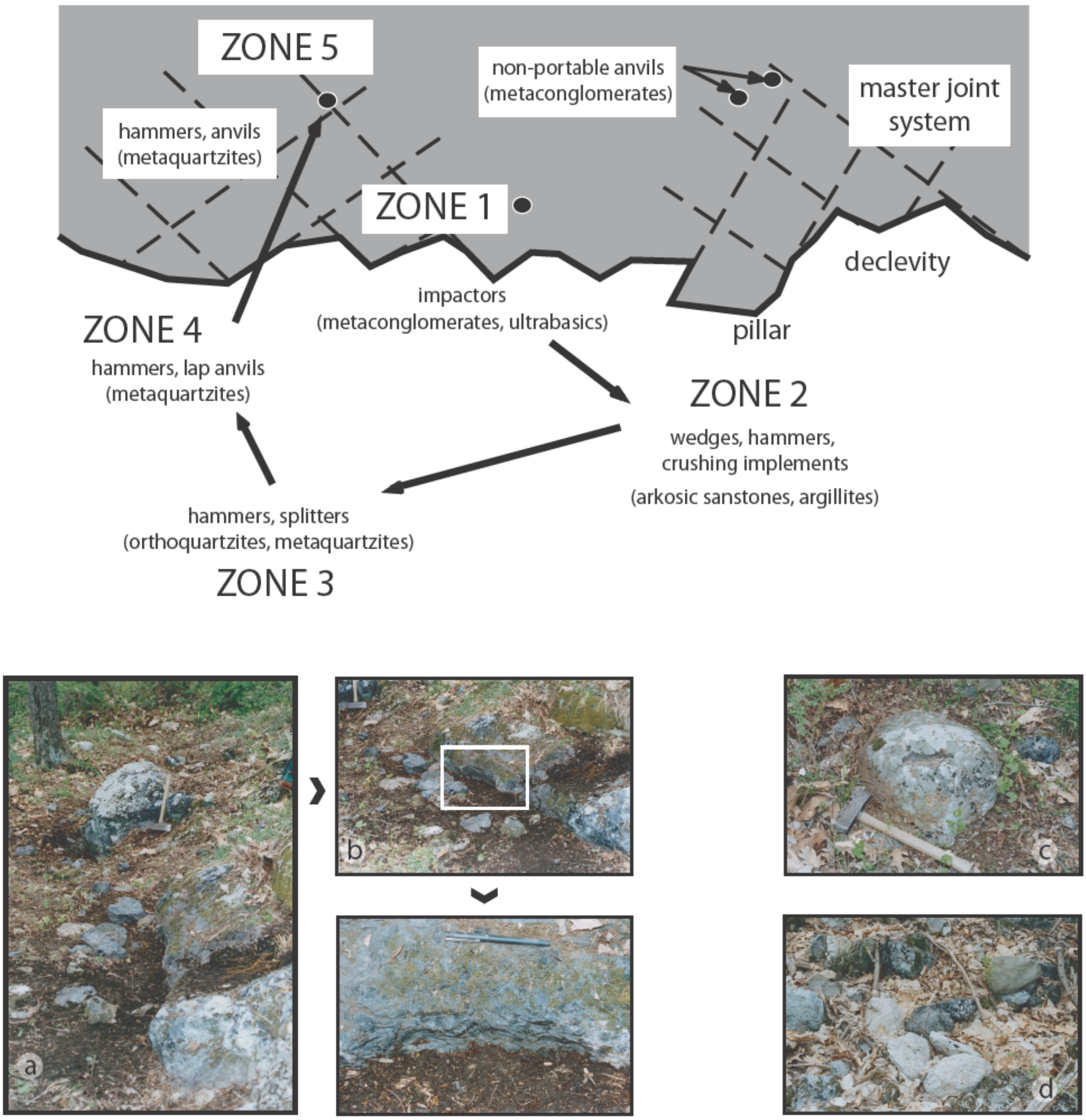

Fig. 3 – Typical First Tectonic Cycle Quarry Plan (LAPORTA, 2005) of the Beaver Run Member, Ontelaunee Formation, at the Beaver Run Standard Section, Sussex County, New Jersey, USA. Images depict: (a) the quarry face, showing excavated neck of block boudinage, along with; (b) castellated surfaces (along with a close-up of cuspate surface overprinted on the castellations) on the block boudins of Zone I, showing limits of quartzite technology; (c) exhumed impactor in front of Zone I; and (d) exhumed instruments and products (ore blocks, middling blocks, and middling cores) of Zones I/II.

experiences, handed down over generations, represents the lexicon of knowledge for the future. The archaeological record suggests that peoples also possessed an empirical understanding of the strength of materials, and were able to select for a specific purpose, the chert types necessary to fulfill a desired need (LAPORTA, 2005; SCHNEIDER & LAPORTA, 2008; LAPORTA *et al.*, 2010, 2017). For example, the Beaver Run Member of the Ontelaunee exhibits specific chert types that are selected for their brittle characteristics, and are useful for the production of single-usage projectile points. Conversely, the Harmonyvale Member of the Ontelaunee Formation possesses a clay-rich chert suitable for manufacture of large bifaces which function as re-utilizable cutting tools. Such empirical knowledge of the strength of raw materials, or an understanding of the rigidity and elastic properties of a rock, require an intimacy with the landscape and is complemented by an accumulated history of experiences, which we have employed as a salient example of the 'folk geology' concept (LAPORTA, 1996, 2009).

Due to the absence of ethnographic data describing the extraction and use of raw material resources along the Atlantic seaboard, data from Australian, Indian, and Canadian aboriginal surveys was carefully employed as a cross cultural comparison (JONES & NEVILLE, 1988; LAPORTA, 2005; unpublished ethnographic notes) to provide flesh to a skeletal record reliant on rock and mineral usage.

The preparation time required for the establishment of the first extraction might be initiated by prospection and evaluation of ore targets, the construction of quarry-support sites, land clearing procedures, complemented with wall or enclosure construction. The collection of raw materials, suitable for the production of a wide variety of extraction implements, is an organized procedure. Time and energy invested in prospection and evaluation of the ore deposit converts the pristine landscape into a multifunction subsistence related site designed for prolonged stays away from stationary base camps. The focused quarry time associated with repeated episodes of extraction render the natural landform into a culturally modified landscape, or standing architecture, in part vitrified (LAPORTA, 1996, 2009; also seen in ethnographic works by HAMPTON, 1999; PATON, 1994). Over time, the quarries are exhausted and transition takes place from an active political reference point on the cultural landscape to a mosaic of memories stored collectively within the minds of those who participated in the extraction of chert and associated activities.

The religious significance of quarries is well-represented in ethnographic literature (GARVAN, 1941; JONES & NEVILLE, 1988; PATON, 1994; HAMPTON, 1999; LAPORTA, 2005). Quarries and stone are said to be guarded by spirits (GARVAN, 1941; BURTON, 1984; PÉTREQUIN & PÉTREQUIN, 1993; HAMPTON, 1999) or are related to specific, or interconnected, myths (PATON, 1994). Even the walk to the quarries, and quarry or non-quarry activities, would have symbolic meaning (SPENCER & GILLEN, 1899, 1904; JONES & NEVILLE, 1988). The detailed mapping and excavation of quarries and analysis of recovered quarry groundstone inventory, suggest that quarry remoteness, and long and enduring activities, may warrant the opportunity for the expression of ritual life and prayer. The most remote quarries, located furthest from navigable waterways, and requiring the greatest energy investment, would also serve as secluded, even mystical, places conducive to activities related to ritual life. The evidence for the presence of possible offerings associated with a giving back process has been documented in excavated contexts, as well as through the detailed analysis of recovered objects (BREWER & LAPORTA, 2005; LAPORTA, 2005; LAPORTA *et al.*, 2010). One must follow the details of the evolution of utilitarian quarry tools, from Zone 1 through Zone 5 (LAPORTA, 1996), in order to elucidate the objects that may serve dual purposes; those with a socio-technical or possibly an ideological function. An understanding of petrology, and petrofabric analysis, is required to tease out the ideological from the vast sea of utilitarian objects (LAPORTA, 2009).

Employing the mining literature (OSBORN, 1907; VON BERNEWITZ, 1931; PEELE, 1941) as a baseline, the following is an inventory of necessary activities associated with the establishment of a quarry, as well as an estimate of the length of time required to complete each task.

Task 1. Prospection (Province), two years;
Task 2. Parameterization (District Subdivisions), one year;
Task 3. Evaluation (Sub-District or Trend), six months;
Task 4. Assay (Quarry), one-two weeks;
Task 5. Land clearing (Quarry), three weeks;
Task 6. Quarry support-site construction (Quarry), one-two weeks;
Task 7. Firewood gathering (Quarry), one week;
Task 8. Gathering of glacially derived rocks for the preparation of quarry tools (Trend or Quarry), one week;
Task 9. Wall construction (Quarry Zone 1), one-two weeks;
Task 10. Scaffolding (Quarry Zone), one week;
Task 11. Fire-setting (Quarry Zone 1), one week;
Task 12. Preparation of Quarry Zone 1 (Zone of extraction), plug-and-feather of chert-bearing strata, one-two weeks.

Quarry preparation tasks do not have to be re-initiated each time extraction takes place. The more repeated extractions do not necessitate the revisiting of Tasks 1 to 4. The re-application of Tasks 5 to 11 may only require maintenance and refurbishing of the site and renewal of resources. Conversely, certain tasks require near complete renewal of resources; such as the replenishing of firewood (Task 7), or the gathering of glacial erratics (Task 8) for the manufacture of new quarry tools. Nelson (1987) observed that stone hammers and wooden handles were cached at metate quarries in the highlands of west-central Guatemala. Only metal picks and hammer heads were transported, since they were sometimes rented or were usually owned. The stone-hammer cache served to accommodate the worker with several instruments, so as not to reinvest a large amount of time gathering during each visit (NELSON, 1987). LaPorta (2005) and LaPorta *et al.* (2010) notes that hammers are sacred objects employed only by task masters and delegated workers at living limestone quarries in southern India. Beehive shaped mounds of glacially derived boulders/erratics are seen dotting Ontelaunee quarries where they occur along drainage divides in the Wallkill Valley. They have been interpreted as caches of raw materials whose petrological characteristics render them worthy of manufacture into quarry tools and instruments.

What follows is a more in-depth presentation of the model of Tectonic Cycle 1 Wallkill chert-quarry activities, previously presented by LaPorta (1996, 2005) and LaPorta *et al.* (2017), that illustrate the behavioral zones of extraction and processing of the chert ore after the twelve preparation steps have been completed.

4. ZONE 1: ZONE OF EXTRACTION

Establishment of the first Zone of extraction depends upon the degree to which geomorphological processes have exposed chert bearing units. The precise location of the first extraction may have resulted in part from the conclusions established by elders situated at a distant base camp, based upon the results of Task 4. Re-locating the potential quarry site is accomplished by following the stratigraphically lowest chert marker horizon for several kilometers along stratigraphic strike, until the prospect site (expression) of the potential quarry presents itself on the glaciated landscape. At that time, Tasks 4 to 11 are initiated, and the quarry site area is prepared. Task 12 would have been completed during the late autumn/ early winter, prior to early spring visitation of the quarry. Archaeological evidence for the essential application of plug-and-feather methods is visible in the field as outcrops whose exposed joint sets are lined with circular indentations, or perforations, encircled with sub-conchoidal flake scars (LAPORTA, unpublished field notes 1978, 1990-1992; LAPORTA, 2005). On many occasions, recycled instruments and country rock are visible protruding from expanded joint sets.

The results of the assay (Task 4) will determine where, stratigraphically, the first Zone of extraction will occur. Of course, the determination is based in part on human needs, both in terms of volume, as well as for specific functions. Therefore the assay will provide insight into the grade of ore, or its overall tenor, and what products could potentially result from the successful extraction (LAPORTA, 1996). During this time, the rigidity and elastic properties of the chert are considered, as well as the desire for aesthetically appealing materials. Therefore the choices are a feedback response echoed from the base camp to the quarry and back again, until a determination has been made.

Plugs are oriented along accentuated and partially sealed joint surfaces, between bedding planes, as well as within the hinges of folds (i.e. $F2_1$) and close-spaced fracture cleavage (i.e. $C4_1$ and $C4_2$). Plugs may be tips of deer antler, or wetted wood fragments of saplings. Recent findings include broken hammerstone fragments and chert blocks wedged within naturally occurring crevices within the rock. Therefore plug-and-feather techniques, along with the application of heat and a reliance on the mechanics of freeze-thaw, are essential. The process invokes a seasonality to quarry activity and is supported by ethno-archaeological data gathered from disparate sources (LAPORTA, unpublished field notes 1978, 1990-1992; LAPORTA, 2005). The pinned area may be checked seasonally, or left isolated and undisturbed for generations. Entire reserves of chert resources may have been subjected to this behavior in advance of the future need for fresh, hydrated chert. The timing of the movement of hunter-gatherers, and their base camps, may be linked centripetally to the discovery, designation, and preparation of chert deposits as is depicted in Tasks 1 through 4. We theorize that the duration of stay, or existence of the stationary base camp, is in part pre-determined by the longevity of known chert reserves. The extreme organizational energy necessary to achieve the establishment of the province, district, and trend subdivisions (BREWER *et al.*, 2000) is echoed in the systematic organization of the quarry itself.

When the location of the prepared plug-and-feathered area is re-discovered along the trend of the outcrop (Task 12), construction of scaffolding may be necessary to reach outcrop along a vertical cliff face (Task 10). Firewood (Task 7) may be concentrated along the base of the outcrop in an effort to craze, or sear, the surface of the chert bed (Task 11). If a water source is present, and is applied, the outcrop may further rupture along the trace of accentuated joints, or in areas of prior plug-and-feather application.

Once the appropriate accentuated joint surface is rediscovered, the task of gathering the appropriate hammerstone and quarry-tool materials is initiated. Precise petrological groupings, and associated weights and dimensions, are gathered from beehive shaped-mounds (Task 8) of glacial erratics concentrated near the quarry area (LAPORTA, 1996). This activity would occur during the period of wall/enclosure construction (Tasks 8-9). The impact wedge and/or the circular impactor is placed over the join between the two contiguous boudinage ($B2_1$, $B2_2$, or $B2_3$). Here the sediments are thinned structurally and the trace of the necked area forms a line between the two adjacent boudinage structures, occurring on either side of the boudin selected for extraction (Fig. 4). The impact wedge/circular impactor is raised and lowered with its upper rounded surfaces in contact with the join of the two boudinage, following the line generated by the necking process. This procedure is repeated on both sides of the boudin until the join is crushed. If the join occurring between two boudins is 'v' shaped, then a focal chisel is added to the equation. The focal chisel serves to concentrate energy of the impact wedge to the precise location of the weakest part of the join between two boudins. Eventually, crushing along the lines of weakness will intersect the precise location of one of the successful plug-and-feathers. At this juncture, the join may yield to the compressive stress of the impact wedge. The impactor is subsequently turned 180 degrees and the tapered wedge end is oriented over the crushed join and repeatedly impacted. The results serve to separate a boudinage from two contiguous boudinage occurring on either side of the center boudin. The cleaning and further definition of the boudin is accomplished with the application of the spatula shaped wedge which is driven into the open spaces between the boudins. The rounded scaling bar is then employed in order to clean any jagged edges remaining on the boudin surface. The first phase of extraction is now completed and a total of four of the six extraction Zone instrument types have been applied to the rock outcrop. The naked boudin is now ready for detachment from the dolomite outcrop, and struts or chocks are placed under the boudin to orient the loosened ore block on a stable bedrock platform. The chocks or struts are the ruptured remains of an older generation of impact hammers and wedges, recycled in order to buttress the chert bed (LAPORTA, 1996, 2005). The rough edges of the ore block are removed through the application of the scaling bar, and work in Zone 1 is complete.

5. ZONE 2: ZONE OF ORE MILLING

Zone 2 activities take place both below, and to the right, of the Zone of extraction (Fig. 3). The work in Zone 2 involves the application of five instruments; the rectangular milling instrument, circular impactor, focal chisel, cobbing or ore dressing hammer, and struts (LAPORTA, 1996, 2005). The process which ensues is a cobbing procedure, and the primary tool required is a rectangular hammerstone referred to here as a milling instrument (LAPORTA, 1996, 2005). The instrument contains a higher percentage of clay than tools employed in the Zone of extraction.

Fig. 4 – Prehistorically worked chert beds in Sussex County, New Jersey, USA. The chert outcrop includes: (a-d) Harmonyvale Member of the Ontelaunee Formation showing multiple generations of petrofabric criss-crossing the raw material, from outcrop scale down to individual chert bed; and (e) frozen behavior showing a hammer prying open dolomite beds to access chert (plug-and-feather method).

The variation in clay content, and overall geometry, is a purposeful cognitive choice for the following reasons. The elevated clay content permits the object to adhere to the surface of the ore block for longer than more elastic rocks would. This fact, combined with the rectangular form, allows the force of the hammer to contact a greater portion of the ore block. The result is a flat, dull impact with an associated deadening, but enduring, force. The impact produces broad flat flakes, or splinters, of dolomite and low-grade chert, without initiating micro-cracks into the chert block. The cobbing process is designed to remove all the remaining dolomite and lower grade chert from the boudin without fracturing the homogenous area where future artifacts will be designed. The milling instruments, and smaller classes of cobbing hammers, are almost exclusively designed from clay-rich, arkosic rocks and argillaceous sandstones and siltstones. The ore block, now partially dressed, can be maneuvered along the stable platform where large circular impactors, and a larger class of focal hammers, can be employed to detach large fragments of the ore block (LAPORTA, 1996, 2005). The large chert fragments are middling blocks and possess flat flake scars or joint surfaces along their long axis. The proximal and distal faces may be faceted by flake scars resulting from the initial dressing of the ore block. If the middling block is largely bound by joint surfaces present from the initial extraction, it remains a middling ore block. However, if the middling ore block possesses a greater surface area of flaked surfaces, than it does original flat joint planes of the ore block, it is referred to as a middling core block (LAPORTA, 1996, 2005).

6. ZONE 3: ZONE OF BENEFICIATION

Ore blocks, and middling ore and core blocks, are positioned along the stable platform, now directly below the former work site at Zone 1. The Zone of beneficiation is the transitional phase of the chain of operation, as this Zone represents the comminution of ore blocks, middling blocks, and middling core blocks (Fig. 3), (LAPORTA, 1996, 2005). Work is focused on the orientation perpendicular ($C4_1$ and $C4_2$) to what are the remnants of the long axis of the former boudin block. Finely spaced joint surfaces, and associated intersecting generations of fanning fracture cleavage ($C4_1$ and $C4_2$), are the parameters for the production of more refined chert ore units, which define the product emanating from this Zone of activity.

The work accomplished within Zone 3 is accompanied by large non-portable and portable anvils, smaller classes of impactors, focal chisels, ore dressing hammers, milling instruments, refinement and re-tooling hammers (LAPORTA, 1996, 2005). The range of petrological groupings necessary to complete beneficiation is possibly the greatest in Zone 3. It includes metaconglomerate, ortho- and metaquartzite, arkosic sandstone, metaargillite, sandstone, gneiss, granite, and ultramafic rocks (LAPORTA, 1996, 2005).

The presence of Zone 1 and Zone 2 type instruments in Zone 3 indexes the continuance of cultural process; the steady and systematic comminution of rock along progressively more finely defined planes of weakness. What is inferred here is that the circumscribed work zones, or specific task areas, are part of an integrated continuum of activities which project from the mind of the quarry worker and permeate the quarry site, much as a flow chart of productivity. The five zones of quarry activity are a continuum of thought processes. At every Zone of activity there is an overlap in process (Schultz, 1985), and a need for recycled objects which index the previous work area. Also, the principle of inheritance applies, which states that the earlier events, and resulting effects, set the stage for the later ones (SCHULTZ, 1985). Both principles are at work and are illustrated by the apparent overlap in function and refinement of the prescribed quarry tool and instrument types.

Classes of smaller impact objects are recycled for use where the joint surfaces are tightly sealed. However, the object which best characterizes this Zone is the circular hammer, which is fashioned from ortho- and metaquartzite. The instruments are roughly circular and approximately one third as thick as wide. Many possess flat upper surfaces and assume a wheel shape after prolonged use and recycling. What is salient is the introduction of populations of more elastic quartzite hammers. The size and form of quarry instruments is now smaller and more streamlined.

The chert is subsequently crushed along the lines of close-spaced joint surfaces until the chert block eventually breaks along one of the planes of weakness (Fig. 3). The numerous generations of tectonism in the region present a challenge to the quarry technician; intersecting joints and fracture cleavages influence the Zone 3 product. Additionally, some generations of fabric are resealed with differing cements. Silica cement presents a challenge due to its hardness; while carbonate cement is significantly softer than silica. Additionally, the possibility exists that some generations of fabric are not recemented. The type and degree of cementation of joints and cleavages often occurs in clustered populations reflecting the results of the structural event. Therefore they are definable in their field relations and can be subsequently exploited, or avoided, depending upon human need. The type and degree to which the recementation process is present can be discerned by how the chert block transmits stress. The degree of homogeneity of the chert block can be subjectively appraised by gently tapping the joint-bounded, rhombic block with a small elastic hammerstone; thereby determining its tenor. Eventually, the large middling block yields along the surfaces of a more finely spaced joint planes and a smaller joint bounded block emerges.

Smaller blocks are collected alongside an anvil and each is dressed with a small refinement hammer. Anvils are the by-product of Zone 1/2 activities and represent ruptured fragments of impactors and impact wedges. The application of the smaller class of ortho- and metaquartzite hammers removes all surface irregularities from the now more tapered rectangular piece of ore. The results of this process include the production of elongate, rhombic fragments of dressed ore, bound on two sides by joint faces and crushed free of surface irregularities.

7. ZONE 4: ZONE OF ORE PROCESSING AND WASHING TABLE

Zone 4 activities are indexed by the introduction of another new class of instruments, the anvils. The presence of stationary, portable, lap, and shoe anvils give testimony to the degree of closeness necessary in order to further refine the complex ore (Fig 3).

The fine array of anvils is associated with an even smaller class of metaquartzite focal chisels and sandstone/siltstone abraders. The hammers of choice are highly elastic ortho- and metaquartzite instruments which have evolved into a circular form. Many of these objects possess finely flaked and ground edges, and are approximately 1:4 in terms of width-to-length ratios.

The joint-bounded, dressed ore is finely crushed along the surfaces of the partially, and completely sealed, finely spaced joints and fracture cleavage (C_1, $C4_2$). The results of this process include five different types of refined ore; the five or greater microlithon bounded unit, the four microlithon unit, the three and two microlithon unit (LAPORTA, 1996, 2005). Refined ore pieces have low weights (ounces to grams) and are bounded by two flat planes ($C4_1$, $C4_2$), which are referred to as domains. The volume of chert occurring between two domains is the microlithon (LAPORTA, 1996, 2005). The ore processing area also serves to sort the domain-bounded microlithons by degree to which diagenesis has taken place and to what degree silica replacement of the host rock is complete (LAPORTA, 2009).

The Ontelaunee Formation preserves a vast quantity of punky and porous stromatactis bearing chert. The outer portions of individual boudins are clay rich. The intermediate parts of the boudin less so, and the centers of many boudins are relatively clay free. This concentric 'layering'of the boudins permits prehistoric workers to grade ore types, establishing the tenor of the ore. Taken a step further, the clay-rich, outer portions of the boudin are more elastic and occur in greater volumes. Conversely, the clay-deficient areas are more brittle ores and occur in much smaller volumes. The intermediate chert Zone contains both an appreciable volume of clay-rich chert, as well as elevated silica. In general, the three zones are characterized as high, intermediate and low grade ore (LAPORTA, 2005), and these important qualifications of the ore determine the desired tool type, and potential function.

The overall tenor of ore is calculated during Task 4 (assay), prior to the development of the Zone of extraction. Such fine-scale work may require the application of water, in order to highlight the various grades of ore, to better define the domains of joints and cleavage ($C4_1$, $C4_2$), and to highlight the effects of diagenesis. It is inferred that Zone 4, and possibly Zone 5, activities may require the application of water, or the presence of a 'washing table', for detailed analysis of the ore (LAPORTA, 1996, 2005).

8. Zone 5: Zone of raw material refinement

Zone 5 includes the greatest bi-modality occurring within the quarry-tool assemblage. At this locale, situated strategically above Zone 1, the focused ore processing occurs centripetally around non-portable anvils weighing over 100 kg each (Fig. 3), (LAPORTA,1996, 2005). At such locations, the results of ore processing of Zone 4 are cached and made ready for the final phase of refinement. The hand-held hammers are the most elastic of the metaconglomerate and metaquartzite instruments, surviving the prior four phases of lithic refinement. Some anvils are associated with struts and occasionally, the full complement of smaller anvils is revealed through excavation as being stacked in the near vicinity of non-portable anvils. This would include large lap anvils, smaller portable anvils and shoe anvils. Entire caches of smaller hammerstones are present, some perfectly circular and spherical. Abraders of sandstone and siltstone, as well as bi-pitted stones designed for fire-making activities, have been discovered.

The non-portable anvils are surrounded by an apron of fine flaking debris and it is here that the first taxonomic flake scars are discernible upon close inspection. Zone 5, domain-bounded chert microlithons are sorted and thinned within the parameters defined by the opposing parallel sets of domains ($C4_1$, $C4_2$). The interplay between intersecting domains and diagenesis is revisited at Zone 5 and the ore units are separated one final time; this time thinning along edges, and basal and lateral edge grinding, is accomplished. The results of the refinement include both large and small classes of block cores, bifacial cores, thick hand-held bifaces, thin bifaces for notching, and flakes for utilization.

In general, four to five, or greater, microlithon ore units evolve into block cores; while those microlithon packages comprised of three to four units are generally serviceable as hand-held bifacial cores and bifaces (LAPORTA, 2005). The outcome will partially depend upon the thickness of the microlithon and its overall dimensions. Thinned bifaces comprised of two or less microlithons may progress on to become notched and hafted depending upon the degree of welding of the domain surfaces period.

Detailed analysis of petrofabric is critical, as the different generations of fabric ($B2_1$, $B2_2$, $B2_3$, $C4_1$, $C4_2$) resulting from multiple episodes of tectonism (T1, T2, T3, and T4) can align themselves parallel or sub-parallel to each other, or intersect at measurable angles. This being the case, further refinement must include a detailed analysis of the fabric on the finest sale. The interplay between fabric, and diagenesis, represents the equation for final refinement and designation for function of the chert as an ore. Detailed analysis is necessary because further refinement of the chert, without careful assessment of intersecting domains of many generations of petrofabric, may result in failure or rupture of the artifact at the workshop, or during use or re-sharpening.

9. Conclusion

Greater than 800 prehistoric bedrock quarries have been discovered in the Wallkill River Valley. The prehistoric chert resources of the Wallkill Valley provide the optimal challenge to the quarry technician, as well as the stone-tool manufacturer. No less than five episodes of tectonic deformation have deformed the chert, which imposes the most challenging task offered to the stone tool worker. Geological field mapping, and laboratory analyses, indicates that the prospection for chert quarries, as well as the preparation of the quarry faces and extraction, is highly dependent upon stratigraphic and structural variables at several scales. The comminution of chert towards the production of refined, utilizable, objects is controlled by fabric at the meso- and micro-scale. Close examination of archived collections, and objects provenancing from Ordovician chert quarries, reveal that the objects are manufactured along lines of petrofabric, with few exceptions. This being the case, the argument for long and enduring stays at prehistoric chert quarries is proposed, coupled with shorter-term revisitations to the quarry outcrop.

The prospection of provinces, districts, and trends requires years of reconnaissance; while the preparation of the quarry itself requires months, and the extraction and refinement processes require weeks of activity. Archaeological evidence suggests that the quarries may be prepared for extraction in the late autumn, with quarry activity ensuing in early spring. Short visitations to quarries may take place again in the early autumn of the following year, for the purpose of recycling objects from previous zones of extraction.

All evidence suggests that there is no expedient process involved in quarry activity in the Wallkill River Valley and conversely, as many as three rigidly timed visits to quarries may take place each year, all orchestrated within the seasonal round of hunter gatherer bands foraging outward from stationary base camps. The elucidation of the elaborate chain of operation, and the associated complex array of quarry instruments, is testimony to the long and enduring stays at the quarries.

The 800 quarries represent only a percentage of the actual number of quarries that exists in the valley. Yet, recovered from the estuaries to the east and south are disproportionate numbers of objects fashioned from Ordovician chert. The close spatial proximity to the estuaries (approximately 30 to 50 miles) of the lower Hudson River, and the presence of abundant aquatic resources occurring within the vicinity of the quarries, may have fueled much of the need for such a tectonized ore type. Certainly, it is important to note that the Wallkill River Valley is also a natural corridor for the migration of peoples and migratory herd animals, and serves to connect the Delaware River Valley with the Hudson River Drainage. The Wallkill River Valley may also have served as portion of the flyway for migratory avian populations.

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The Neolithic Spiennes Collection at the Royal Museums of Art and History (RMAH, Brussels, Belgium)

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Abstract

In the course of the National Archaeology Collections Inventory Project (NACIP), the RMAH's artefacts collected from the Neolithic flint mining complex at Spiennes (Mons, Belgium) have been thoroughly re-identified and classified according to their original contexts (if possible). An exhaustive inventory and the retrieval of all scientific documentation concerning the collection have made a detailed overview of the most important arrivals of this collection at the museum. The electronic accessibility of the collection has furthermore facilitated its management that will, in turn, promote renewed scientific research.

Keywords: Spiennes, Neolithic, prehistoric flint mining, Royal Museums of Art and History, history of museum collections.

Résumé

Au cours du projet NACIP (National Archaeology Collections Inventory Project), le matériel des Musées royaux d'Art et d'Histoire (MRAH, Bruxelles) provenant du complexe minier néolithique de Spiennes (Mons, Belgique) a fait l'objet d'une ré-identification et d'un reclassement des objets selon leur contexte d'origine (quand cela s'est avéré possible). Un inventaire exhaustif ainsi que la compilation de la documentation scientifique liée à la collection a permis d'obtenir une vue complète de l'arrivée des ensembles les plus importants aux Musées. La numérisation de l'inventaire de la collection simplifie sa gestion ce qui, à son tour, facilite la recherche scientifique.

Mots-clés *: Spiennes, Néolithique, exploitation minière préhistorique, Musées royaux d'Art et d'Histoire, histoire des collections.*

1. Introduction

The RMAH's National Archaeology Section preserves a very important and large collection of artefacts collected from the Neolithic flint mining complex at Spiennes (Mons, Belgium). It was constituted from 1867, shortly after the first discovery of the site, until 1966. Several fortuitous findings, surface explorations and archaeological campaigns led up to the amassing of more than 20,000 artefacts and ensembles in the museum's storage rooms (Fig. 1). In total, more than 350 cases and wooden trays were filled with discoveries in flint, chalk, bone, ceramics and antler. In the course of NACIP (National Archaeology Collections Inventory Project), initiated in 2012 and funded by the Belgian Science Policy Office, the entire National Archaeology Collection, including the Spiennes findings, underwent a complete facelift. This resulted in the re-shelving of the items in adequate storage conditions and in the constitution of a digitalised inventory. As a result of NACIP, renewed scientific research is triggered since the complete collection is now easily accessible.

This paper presents an overview, in chronological order, of the most important arrivals of this Neolithic collection at the RMAH, associated with both key-moments of the early on-site archaeological activity, as well as movements of the collection inside the institution. We will furthermore focus on the recently established inventory that permitted to retrieve information on, in some cases, long lost discoveries.

Year of arrival	Inventory number	Mode of acquisition	Context of discovery	Type of find (number of inventory entries)
1867	B000451	Invoice from the Interior Ministry	Found by the workers in the construction trenches of the railway	Isolated find (1)
1892	B000812	Donation M. L. Cavens	Excavations of MM. Cavens and de Munck in 1887	Excavated material lacking contextual data (55)
1902	B000953	Purchased from M. L. De Pauw	Excavations of L. De Pauw and E. Van Overloop in 1889	Excavated material lacking contextual data (4)
1922-1923	B002433	Purchased from M. A. Cels	Excavations of L. De Pauw and E. Van Overloop in 1889	Excavated material lacking contextual data (10)
1923	B002554	Donation M. L. Lequeux	Context of discovery unclear	Excavated material lacking contextual data among which fake pieces (6)
1925	B002644	SSE excavations	Excavations led by A. de Loë and E. Rahir between 1925 and 1928	Excavated material with contextual data (186)
1948	B003450	Context of arrival unknown	Artefacts from the collection of A. Cels	Isolated artefacts (8)
1923	B003451	Context of arrival unknown	Artefacts from the collection of A. Cels	Isolated artefacts (1)
1963	B004377	Purchased from M. J. Hamal-Nandrin	Excavation campaigns between 1916 and 1930	Excavated material lacking contextual data (16)
1966-1967	B004389	Purchased from M. J. Verheyleweghen	Excavation campaigns between 1949 and 1964	Excavated material with contextual data (255)
1928-1932	B005865	SSE excavations	Campaigns led by J. Breuer between 1928-32	Excavated material lacking contextual data (29)
date unknown	B005871	Donation M. L. Cavens	SSE Excavations led by A. de Loë between 1912 and 1914	Excavated material lacking contextual data (52)
1926	B005879		Fake chalk pieces made at the Museum at E. Rahir's request	(1)

Fig. 1 – Table presenting a non-exhaustive review of the constitution of the Spiennes collection at the RMAH © KMKG-MRAH, Brussels.

2. Brief historiography of the RMAH's Spiennes collection

It is in 1867 that the first shafts of the Neolithic flint mining complex at Spiennes are discovered during the construction of the railway connecting Mons to Chimay. This discovery will lead to a century of intensive research and archaeological excavations. The same year, two urns were found in the construction trench and sent to the museum (then Royal Museum of Armour, Antiquity and Ethnology, located in the Halle Gate) by the Interior Ministry. They receive the inventory number B000451. However, the precise circumstances of this discovery remain unclear.

In the year 1887 Baron A. de Loë and archaeologist E. de Munck undertake the first on-site excavations (DE LOË & DE MUNCK, 1889). They examine a mine shaft of 8 m deep as well as some workshops and upper parts of other shafts. A total of 1108 artefacts were collected, consisting of flint tools, roughouts, hammers, antler and bone tools. The artefacts are later bought by Earl L. Cavens, collector of archaeological artefacts and antiquities and patron of the museum. The items that are illustrated in the publication bear a label – probably stratigraphic –, while as the rest of the material cannot be formally identified.

The National Archaeology collections (formerly called Old Belgium), including the Spiennes artefacts, are transferred from the Halle Gate to the newly constructed 'Cinquantenaire Palace' in 1889, where they are stored in the north wing. The same year, geologist and palaeontologist L. De Pauw excavates a mining feature together with E. Van Overloop, archaeologist and the Museum's head curator. (DE PAUW & VAN OVERLOOP, 1889-1890). In 1902, L. De Pauw sells a large part of his collection to Earl L. Cavens and some of the artefacts to the Museum, where they are inventoried under number B000953. In 1892, L. Cavens buys the private collection of a certain E. Gilson, private collector, and donates it later in the same year to the Museum (inventory numbers B000811 and B000812), together with the excavated material previously bought from E. de Munck and L. De Pauw. Unfortunately, the material of these formerly separate collections was brought in without any catalogue and jumbled together before its arrival.

In 1903, the State Service for Excavations (SSE) is created within the museum. Between 1912 and 1914, A. de Loë leads several archaeological campaigns at Spiennes for the SSE, financed by L. Cavens (DE LOË, 1925). During these years, he excavated two mine shafts and adjacent galleries, several workshops and a so-called sunken-floor hut, a type of structure that today would be identified as a shaft head. The excavations deliver more than 1500 artefacts: picks, axes, roughouts, antler, hammers, potsherds and engraved chalk blocks. The material was sent and stored at the Museum, where it never left the original boxes, bearing no other identification than 'Spiennes'. At its arrival, the material was not registered in the collection's inventory. It is thanks to the invoice on the post label reading 1912 that the boxes could be associated with de Loë's excavations. The inventory number B005871 was attributed to the ensemble.

The collections of Old Belgium will move in 1922 to the wing situated alongside the Nerviens Street (Fig. 2). Several storage rooms will furthermore be constructed to host the large quantity of material excavated by the SSE.

One year later, in 1923, L. Lequeux donates his private collection of over 300 pieces to the Museum (inventory number B002554). Only a dozen of items could be formally identified as part of this collection. They cannot be linked to any excavation or publication. Later found guilty of producing false artefacts, the scientific value of the entire Lequeux collection can be doubted today: at least six false picks and axe roughouts have been identified (Fig. 3). The same year, the Belgian State acquires the private collection of A. Cels, inventoried under number B002433. A. Cels appears to have collected this material from the excavations of L. De Pauw and E. Van Overloop at the end of the 19th century. However, the circumstances of these particular discoveries remain unclear (CELS & DE PAUW, 1885-1886).

In the following years, the interest of the SSE for Spiennes stays marked. Between 1925

Fig. 2 – Picture of one of the collection's former exhibition rooms © KIK-IRPA, Brussels.

Fig. 3 – L. Lequeux's false picks and axe roughouts © KMKG-MRAH, Brussels.

and 1928, two successive excavation campaigns are led by A. de Loë and E. Rahir, during which they realised 1040 surveys and excavated 34 so-called 'sunken-floor huts' and 23 small hearths (DE LOË & RAHIR, 1929). The findings include numerous flint and antler tools, potsherds, animal bones, chalk objects and human skulls. They are separated in boxes per hut and bear the inventory number B002664. A section of each hut is included in the publication; some of the objects can thus be roughly replaced in the described stratigraphy.

L. Lequeux makes a 'sensational discovery' in 1924, consisting of chalk bowls and statues presumably excavated in a mine shaft, on behalf of the geologist A. Rutot who then publishes the material (RUTOT, 1926). The conditions of the discovery, without witnesses, as well as the artefacts' authenticity are directly questioned by the scientific community. E. Rahir, then assistant-curator at the Museum, asks his assistant to create identical chalk artefacts in an attempt to prove how easily such items could be fabricated. This resulted in 48 fake chalk pots, figurines and axes, still kept at the Museum (Fig. 4) under the inventory number B005885 (RAHIR, 1926).

Between 1916 and 1930, professor and archaeologist J. Hamal-Nandrin leads several excavation campaigns while constituting a large collection of artefacts, to which he will add received or bought items from other collectors. He numbers and describes each item in his handwritten catalogue, still associated with the collection. In 1924, J. Hamal-Nandrin excavates and publishes 11 so-called huts and 3 workshops with J. Servais, curator of the Archaeological Museum of Liège (HAMAL-NANDRIN & SERVAIS, 1925). This publication as well as the catalogue is regrettably succinct; the pieces from the excavations bear little contextual information and cannot be linked to any surface plan or stratigraphic section. Alongside his own research, he hires the local amateur archaeologist C. Stevens to excavate on site and pays for the material resulting from them. After his death, the entire Hamal-Nandrin collection is sold to the Museum. It will be inventoried in 1963 under the number B004377.

During the years 1928 to 1930, J. Breuer, then *attaché* at the Museum, supervises several archaeological campaigns before becoming director of the SSE (BREUER, 1930). He is the first to identify temporary open air mining zones and discovers several mine shafts and so-called huts by digging modern test trenches (COLLET *et al.*, 2008, p. 46). Apart from pictures of his activity that are stored at KIK-IRPA, the results of his excavations are only scarcely published. They contain no

Fig. 4 – Chalk artefacts fabricated for E. Rahir at the RMAH in 1926 © KMKG-MRAH, Brussels.

situation plan and few stratigraphic data, making it difficult to link the large quantity of collected material, inventoried under number B005865, to the exact circumstances in which it was found.

In 1945, the storage rooms are renovated and new wooden storage cases are built. The collection is then stored in numbered boxes placed by geographical order. Given the volume of the Spiennes ensemble, half of the material is left in the old boxes next to the new storage. A makeover of the exhibition room two years later (Fig. 5), causing changes in the presented artefacts, will result in some mistakes: several items are relocated in wrong boxes and are attributed to erroneous inventory numbers due to the lack of labels identifying the ensembles.

It is in 1966 that the last set of artefacts from Spiennes arrives at the Museum when archaeologist J. Verheyleweghen sells his private collection, resulting of more than 15 years of excavations on the site. This collection, inventoried under number B004389, consists of more than 7000 pieces found in 250 specialised locations. Each artefact is numbered and described in a special catalogue, still associated with the collection, indicating a precise plot number and the type of settlement (workshop, hut) for each artefact. The excavations and their results were thoroughly published (VERHEYLEWEGHEN, 1961, 1963).

The makeover of the National Archaeology exhibition room in 1991 entails changes in the exposed artefacts. This will lead to new errors, since several pieces returned to the storage rooms and were thus isolated from their original contexts.

In 2012, the NACIP project is launched. Missing labels, erased inventory numbers and the involuntary accumulation of artefacts had endangered scientific exploitation of the collection since several decades. In the framework of NACIP, all Spiennes artefacts have been identified, numbered, described, integrated in a digitalised database (Access) and stored in renovated storage rooms. Thanks to the retrieval of the scientific data

Fig. 5 – Picture of the Spiennes collection as presented in a showcase of 1957 at the RMAH (LEKIME, 1971).

related to the collection (publications, excavations reports, private catalogues...), the Museum staff was able to draw up a correct and up to date historiography of the items.

3. REDISCOVERIES

The NACIP project brought new insights into the Spiennes collection, enabling the re-identification of some of the artefacts previously overlooked by the archaeologists and Museum staff.

The findings of the excavations of 1887 contained 12 engraved chalk blocks, some still bearing ochre traces, that were wrongly inventoried as 'casts of the flint mine walls with pick traces'. These blocks were recently studied by A. Teather and have now been identified as intentional engravings (TEATHER, 2011). They are henceforth available for more in-depth study.

Amongst the findings of the 1925 campaign, are axes and small bowls made of chalk found in different huts. These artefacts, at first considered as castings and then believed to be fake because of their resemblance to the pieces fabricated by E. Rahir in 1926, bear an original hand-written label identical to those of the rest of the excavated material. They are also described in the publication by the excavators (DE LOË & RAHIR, 1929). Today, there is no reason to question their authenticity; the pieces are thus legitimately kept amongst the rest of the campaign's material.

4. CONCLUSION

The NACIP project clearly shows the interest of retrieving all long-lost existing scientific documentation (excavation reports, publications, archives, etc.) of items that have been stored for many years and that are considered as well known and studied. Originating from a renowned site, the Spiennes material still reserved some surprises while beneficiating from a modern investigation. Even if the scientific potential of some units is clearly limited, as the contextual information is old and in some cases clearly lacking, others will certainly have something to bring to the knowledge of this major Neolithic site in the future. A next crucial step in the inventory process of the Spiennes collection is the further verification of the inventoried objects and the integration of the collected data in the museum's central database, making the information thus available to the public via the museum's online catalogue (www.carmentis.kmkg-mrah.be).

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In search of the chocolate flint mine in Orońsko (PL1, Southern Poland): New data for analysis of exploitation and use of flint in north-western part of its outcrops

Katarzyna KERNEDER-GUBAŁA

Abstract

Initial results of recent field and archival researches conducted in Orońsko in the northernmost part of the 'chocolate flint' outcrops in Central Southern Poland are presented here. Orońsko are mining sites known since their discovery and researches conducted by Stefan Krukowski during the 1920s. In 1935 he found the remnants of mining shafts connected, in his opinion, with Late Palaeolithic exploitation. Recent analysis of archival data and field researches led to the discovery of other mining shafts located in Orońsko of the Late Palaeolithic period, which were dated using 14C method on charcoals.

Keywords: Orońsko, flint mining, chocolate flint, Late Palaeolithic, Poland.

Résumé

Cet article présente les résultats préliminaires de recherches récentes menées sur le terrain et dans les archives à Orońsko, dans la partie la plus septentrionale des affleurements de «silex chocolat», dans le centre sud de la Pologne. Orońsko est déjà connu pour ses sites miniers, découverts et investigués depuis les années 1920 par Stefan Krukowski. En 1935, il a découvert les vestiges de puits de mine dont l'exploitation remonterait, selon son opinion, au Paléolithique supérieur. L'analyse récente des données archivistiques ainsi que des recherches de terrain ont mené à la découverte d'autres puits de mine à Orońsko, lesquels ont pu aussi être datés du Paléolithique supérieur par la méthode du ^{14}C appliquée sur des charbons de bois.

Mots-clés *: Orońsko, mines de silex, silex chocolat, Paléolithique supérieur, Pologne.*

1. INTRODUCTION

The chocolate flint mine in Orońsko is amongst other known and studied sites connected with the extraction and processing of flint in the region. The mine was registered under number PL1 in the catalogue *5000 Jahre Feuersteinbergbau: die Suche nach dem Stahl der Steinzeit* (WEISGERBER *et al.*, 1980, p. 199). Its research importance in terms of mining and processing of the 'chocolate flint' is considerable, especially for the most distant periods of the Stone Age. The area in question is considered as one of the oldest flint mines in Poland. This fact, combined with the analysis of archival data and flint materials, inspired the author to conduct a research field project 'Exploitation and processing of chocolate flint during Palaeolithic and Mesolithic in the North-Western part of its deposits based on non-invasive archaeological and geophysical research and test-trenches', financed by National Science Centre (UMO-2015/17/N/HS3/01279). This paper confronts initial results of the recent field research carried out in the Orońsko region with the background of archival data.

2. LOCATION OF OROŃSKO AND CHOCOLATE FLINT OUTCROPS

Chocolate flint is considered as one of the highest quality flints in Poland. It can vary in colour, although it is generally brown. Based on its macroscopic features, chocolate flint has been divided into 11 main categories and their sub-varieties (BUDZISZEWSKI, 2008, p. 45; KAMIŃSKA SZYMCZAK & SZYMCZAK, 2002; SCHILD, 1971, 1976, p. 148-150). Studies in this regard have also been conducted recently (GRAFKA *et al.*, 2015; BRANDL *et al.*, 2016).

The quarries of chocolate flint are located in the north-eastern Mesozoic margin of the Holy Cross Mountains, spanning across an area of nearly 90 kilometres (Fig. 1). These silicites can be found in limestones and residual karstic clays, as well as in glacial deposits (BUDZISZEWSKI, 2008, p. 49-50; SCHILD, 1971, p. 150). Orońsko is a village located in the north-westernmost part of these deposits, on the border of the margin of the Holy Cross Mountains and the Radom Plain, in Central-Eastern Poland (Szydłowiec County, Mazowsze Province; Fig. 1). The region is crossed by the Oronka River, on the left bank of the Vistula River (BERNAT, 2004).

3. RESEARCH BACKGROUND

Chocolate flint outcrops, together with extraction points and workshops, have been discovered and studied since the 1920s, firstly by Professor Stefan Krukowski (leading Polish prehistorian) who, together with Jan Samsonowicz, detected and investigated the area of those quarries in Central-Southern Poland (KRUKOWSKI, 1922, 1923; BUDZISZEWSKI, 2008).

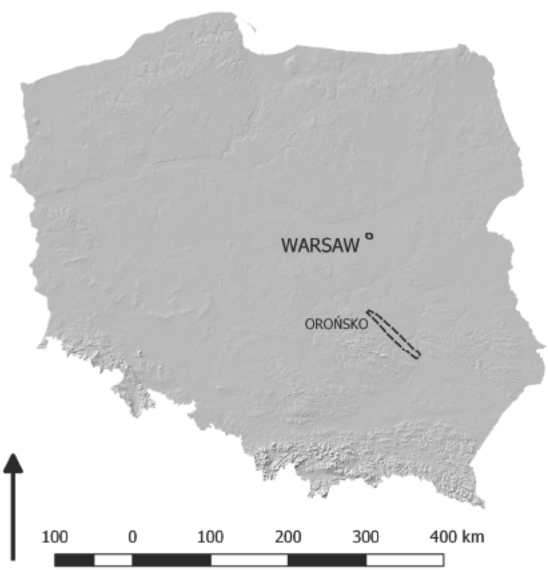

Fig. 1 – Location of the chocolate flint outcrops (black dashed line) and Orońsko municipality, Masovian voivodeship.

First archaeological excavations in the chocolate flint mine took place in Orońsko (Site II) in 1935. Small trenches lead to the discovery of several prehistoric shafts. Based on technological and typological analysis of the artefacts, they were dated to the Late Palaeolithic (BUDZISZEWSKI, 2008, p. 33; KRUKOWSKI, 1939-1948). In 1968, more surface research projects were carried out and their results helped classify different types of chocolate flint (SCHILD, 1971). During that research, many potential flint extraction spots were recorded throughout the outcrops (SCHILD, 1971, 1976, p. 153-154, 160-161, 1997, p. 121). Regular excavations in other mining sites ultimately led to the discovery of chocolate flint mines from the Neolithic and Bronze Age (BUDZISZEWSKI, 2008, p. 37; LECH & LECH, 1984, 1995; SCHILD, 1995, 1997; SCHILD *et al.* 1985). The processing and distribution of chocolate flint has therefore been central to research which has revealed that material was distributed among Stone Age societies across distances of up to several hundred kilometres (CYREK, 1981, 1995; KRUKOWSKI, 1922, 1923, 1939-1948; SCHILD, 1971, 1976, 1997; SULGOSTOWSKA, 1989, 2005, 2008).

4. ARCHIVAL DATA ANALYSIS

The largest piece of archival data available for analysis comes from Krukowski's field research in the area known as 'Orońsko Mines', which consists of the extraction sites in Orońsko and the surrounding area of Chronów and Guzów (BUDZISZEWSKI, 2008; SCHILD, 1971). Throughout the surface research and excavations, Stefan Krukowski collected several thousand artefacts. The remaining data comes from the surface surveys conducted in the late 1970s (SCHILD, 1971) and early 1980s, collected thanks to the implementation of the Polish national program for regular surface surveys - AZP (*Archeologiczne Zdjęcie Polski* - Archaeological Image of Poland).

4.1. Data from Stefan Krukowski's research

The excavations conducted by S. Krukowski, in a 10 x 2 m trench, exposed several flint extraction shafts with the diameter of

1.2-2 m and up to 3.2 m deep, sunk in karstic clays (KOZŁOWSKI, 2008; KRUKOWSKI, 1939-1948). It is supposed they were exploited during the Late Pleistocene by Final Palaeolithic Arched Backed Piece (ABP) or Masovian societies, although they included some Early Bronze Age components as well (BUDZISZEWSKI, 2008, p. 91; SCHILD, 1971, 1976, p. 151). S. Krukowski named his discovery 'the Orońsko industry' (KRUKOWSKI, 1939-1948), although the hypothesis was later debunked since some artefacts he had described turned out to be part of Palaeolithic assemblages, whereas others came from different periods of the Stone and Bronze Age (BUDZISZEWSKI, 2008; KOZŁOWSKI, 2008; SCHILD, 1971).

The number of artefacts from Krukowski's excavations reaches over 5000 pieces. Almost 15 % of them consist of natural fragments of flint concretions and fragments with testing scars. There are very few pre-cores (11) and only 88 cores. Flakes, together with flake fragments, constitute the largest group of artefacts and make up for almost 45 % of all the pieces. Most are full cortical pieces, or at least by 50 % of cortex, and are massive. Multidirectional flakes also come from the core preparation stage or core rejuvenation. There were a total of 579 blades and blade fragments. Amongst the assemblage, pieces classified as 'mining tools' were distinguished. One may observe several settlement phases based on the material obtained from the shafts in Orońsko, as already hinted by earlier studies (for example SCHILD, 1971; BUDZISZEWSKI, 2008; KOZŁOWSKI, 2008). However, horizontal distribution of artefacts could not be performed due to lack of usable data and singling out chronological differentiation of the shafts was not possible. Vertical analysis, nonetheless, brought along some new ideas by indicating the presence – albeit limited – of components of flint artefacts connected with the bifacial technology from the Early Bronze in the upper layers (up to 1.4 m). The Final Palaeolithic assemblages are the other frequent components that went all the way to the bottom of the shafts. Some of them hint at younger Tanged-Point Culture (Masovian), because of the characteristic cores, pre-cores and blades, although others (especially at the lowest cultural levels) can be linked with another Final Palaeolithic culture, the Arched Backed Piece (Fig. 4:1). Additionally, several Late Mesolithic or Early Neolithic cores were also recognised.

4.2. Other archival data

Other archival data was also gathered during the AZP program in the region, i.e. starting 1985 and other projects. In total, over 250 sites were recognised in the area of Orońsko municipality (approx. 80 km^2). The sites that are generally dated back to the Stone Age are numerous. Most of them could not be dated more precisely due to their non-specific, small assemblage but 30 sites are dated to the Late Palaeolithic. These are the remains of the extensive processing workshops of chocolate flint, as well as hunting camps. The smallest number of sites is dated to the Mesolithic, while mostly they belong to the Neolithic and Early Bronze Age. There is also a large group of sites whose dating is unknown and whose artefacts are not currently available for analysis (see KERNEDER-GUBAŁA *et al.* 2017; Fig. 2).

5. RECENT RESEARCH IN THE OROŃSKO REGION

The purpose of the new research project conducted by the author in 2016 was to obtain more data for particular analysis of the mining and processing of flint during the Palaeolithic and the Mesolithic in this area. The surface surveys, test trenches as well as geophysical and geomorphological studies have been carried out and are yet to be concluded.

Currently, the extraction spots in the north-western part of the chocolate flint outcrops are visible only because of the presence of a large number of mixed flint artefacts from different chronological periods and stages of exploitation, as well as limestone nodules on the surface. The considered area has been highly modified by modern agriculture and no visible mining relief has been preserved (BUDZISZEWSKI, 2008; SCHILD, 1971, p. 41, 42, 1997, p. 120). As for now, the best results have been achieved using the method of surface survey and test trenching.

5.1. Surface survey

In 2016 field studies allowed to select the areas for more particular studies using geophysics and test trenches. The most likely area to contain traces of older excavations and mining shafts in further exploration was identified on the basis of preserved archival field documentation and source literature.

During fieldwork, over 30 sites located within the range of a few kilometres away from the outcrops known from earlier studies were re-examined. It was possible to distinguish five extraction places in the mining area: Orońsko 2 (where Krukowski discovered mining shafts), Guzów 13, Guzów 3, Guzów 15 and Chronów Kolonia Górna 2 (Fig. 2). Based on flint samples collected from the surface, Palaeolithic and Bronze Age concentrations were recognised. Some other components could be found there as well, but not in substantial concentrations. They dated back to the Late Mesolithic and Early Neolithic periods. Other sites were additionally identified near the mining fields, namely workshops and camps/settlements. These are the Final Palaeolithic and Early Bronze Age workshops located near the mining fields, as well as camps and settlements that can be dated to the whole Stone Age.

5.2. Test trenches

Test trenches conducted in the mining fields allowed to obtain new data. First, the tests were dug out at regular distance in the area of the probable place of Krukowski's works in Orońsko Site 2 and in other places at regular distance, up to the supposed border of the mining area. In some cases, a large number of artefacts, pieces of concretions and limestones found on the surface of the fields did not confirm the presence of underground mining features because of the agricultural activities through ages, which probably 'extended' the original range of mining fields. With that being said, in two of the trenches, the remnants of cavities and other objects were confirmed a few hundred metres from the probable place of Krukowski's excavations. The most interesting results were achieved in two small trenches (about 2 x 3 m): Orońsko 2/I3 and Orońsko 2/I4 (Fig. 4).

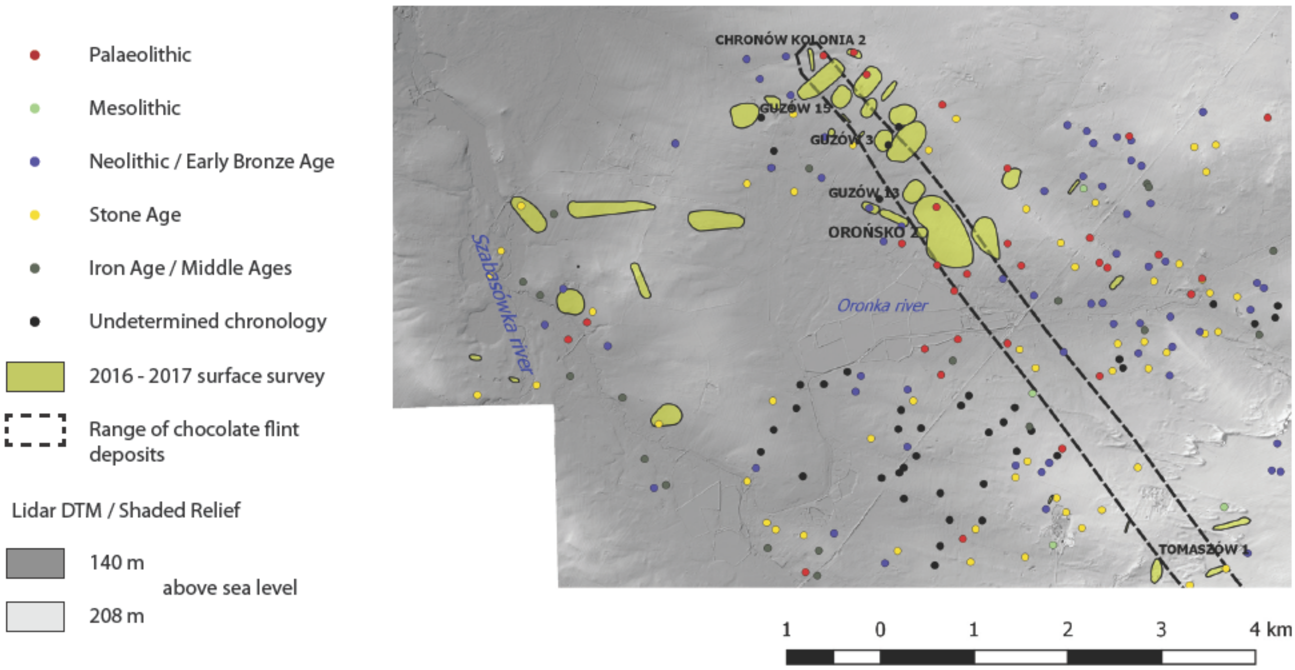

Fig. 2 – Location of archaeological sites in Orońsko municipality. Shaded relief: N. Buławka.

Fig. 3.1

Fig. 3.2

Fig. 3.3

Fig. 3.4

Fig 3.5

Fig 3.6

Fig 3.7

Fig. 3 – Field photographies from excavations on site Orońsko 2. Trench I3 (nr 1-2); Trench I4 (nr 3-7).
3, 4: an outline of Shafts 1, 2 and 3 (red numbers) at a depth of 0.6 – 0.8 m from the surface;
5: profile of Shaft 1 and limestone layer on the bottom with visible pieces of Shafts 2 and 3 at a depth of 3.2 m;
6: detail of Shaft 1; 7: bottom of Shaft 2.
Photos: K. Kerneder-Gubała.

Fig. 4.1

Fig. 4.2

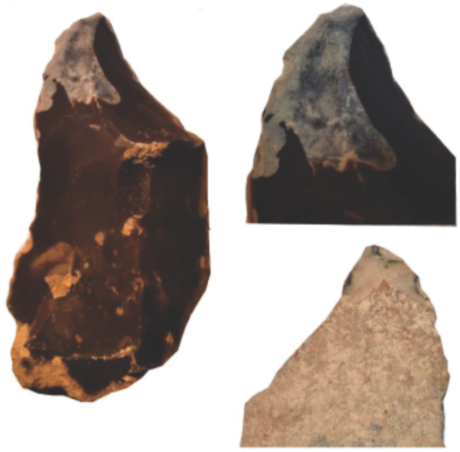

Fig. 4.3

Fig. 4.4

Fig. 4.5

5 cm

Fig. 4.6

Fig. 4.7

Fig. 4.8

Fig. 4.9

5 cm

Fig. 4 – Flint artefacts from Orońsko researches. 1: backed piece from Krukowski's excavation (collection from State Archaeological Museum, Warsaw); 2: half-product of bifacial axe, Trench I3; 3: mining tool from Trench I4; 4-6: cores from Trench I4; 7-8: bone tools from Trench I4; 9: a nodule from Trench I4. Photos: S. Buławka and K. Kerneder-Gubała.

5.2.1. Orońsko 2, Trench I3

In Trench I3, a clearly visible clay outline of a pit was distinguished. It was surrounded by light, weathered products of limestone. Its structure was fairly basic. It had a diameter of approximately 2 x 2.5 m and it was about 1.5 m deep (Fig. 3:1-2). The flint materials are homogeneous and are connected with the bifacial production of tools. Most frequent are flakes, including multidirectional flakes, some blades and flake cores. In the filling of the pit, there were also initial products of bifacial reduction – half finished products of axes (Fig. 4:2). As recent results indicate, raw materials might have been obtained from karstic clays with the use of simple methods. This trench contains some mining tools in the form of retouched large cortical flakes or reused cores and pieces of sharp-edged nodules.

5.2.2. Orońsko 2, Trench I4

In Trench I4 a few illegible outlines of archaeological features were distinguished 40 cm below the topsoil (Fig. 3:3-4). On this level, remnants of workshops and levelled mining comprising of waste products, nodules and limestone fragments were observed. By carrying out half excavation of one of the main extraction features, plus sections of at least two others, it was possible to establish a chronology and relationship between them. It was concluded that a total of five extraction shafts were sunk into each other. They were likely to have been backfilled with the remnants of mining heaps, which probably successively collapsed into the shafts left open after their exploitation, or they were initially covered with waste from other shafts.

The uncovered shafts are at least 3.5 m deep and sunk not just in karstic clays, as it was thought after Krukowski's excavations, but also in the primary limestone rock (Fig. 3:5-7). This suggests that methods of exploitation were more advanced in this period, than was previously thought on the basis of other Palaeolithic mines (GINTER, 1974).

From this trench more than 3000 artefacts have already been collected. The most numerous were nodules and nodule fragments with testing scars, flakes and blades, some cores and very little tools. Raw material is the dark brown chocolate flint that used to reside here in tabular and irregular concretions. Most of the artefacts were white – patinated (Fig. 4:4-6). The cores showed different stages of exploitation, but generally initial or broken ones. They were mostly single-platform, exploited with the use of hard hammer, what can be observed not only on cores, but also on flakes and their butts. Although there were some double platform cores, cortical flakes and blades point to the first stages of exploitation. Among flint tools, the most numerous were irregular, macrolithic mining tools made from nodule or core fragments, with simple preparation (Fig 4:3). In the filling of Shaft 1 and 2, animal bone fragments were found. In Shaft 1, there are unused pieces of what might have been an elk or a deer, and in Shaft 2 there are bone tools, possibly used for mining activity, as use-wear and experimental analyses indicate (OSIPOWICZ *et al.*, 2019; Fig. 4:7-8).

Two 14C dates obtained from the shaft filling (Fig. 5) presented in this paper suggest that the mine dates back to the end of the Allerød oscillation or the beginning of the Early Younger Dryas, and according to techno-typological analysis, it can be linked to the Final Palaeolithic Arched Backed Piece Technocomplex, as well as the Tanged-Point Cultures. Eight more 14C dates obtained from the charcoals and one from the bone mining tool confirmed early age of the mine (OSIPOWICZ *et al.*, 2019).

6. CONCLUSION

Without a doubt, in the Orońsko region one can observe sites whose assemblages are connected with flint extraction and initial processing in the range of mining fields as well as processing workshops, camps and settlements of further stages of exploitation, located near the mining fields. Exploitation of flint with the use of mining method is confirmed in this area at least since the Late Palaeolithic. Elements of flint assemblages collected during the surface surveys from some of the neighbouring workshops can be dated even to the Earlier Palaeolithic Cultures. Undoubtedly, very clear traces of Early Bronze Age flint exploitation and intensive processing can be confirmed here.

As indicated by the research studies conducted so far, chocolate flint was used from the Middle Palaeolithic onwards, but started being acquired along with the use of mining methods, confirmed since the Upper Palaeolithic (SCHILD, 1976, p. 162). The most intensive extraction and processing was observed in the Final Palaeolithic and Late Mesolithic sites (KOZŁOWSKI, 1989; SCHILD, 1971, p. 41, 42). Chocolate flint was very popular also in the Neolithic, as well as during Bronze Age, when many interesting tools were made of it.

The richness of this area is hinted at by Stefan Krukowski already in the early 20th century. Despite the fact that agricultural activity remains very intensive in this region, thereby causing the destruction of the mining

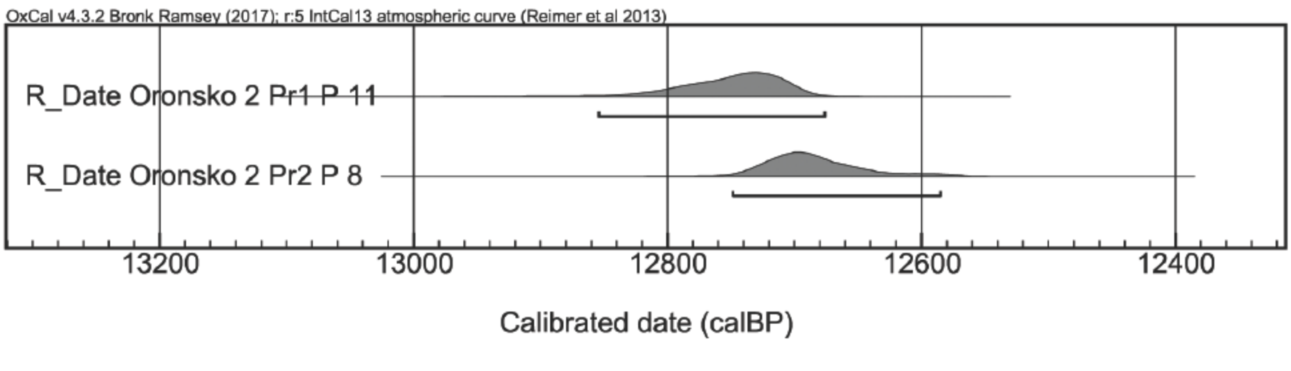

Fig. 5 – Calibrated 14C dates on charcoal from Trench I4, shafts 1 and 2, Poznań Radiocarbon Laboratory, Poland.

fields, there are numerous assemblages that still exist on the sites.

The region in question must have played a very important role as a centre of flint mining within the north-western part of the chocolate flint outcrops.

According to recent studies, it can be confirmed that Orońsko is one of the oldest flint mines in Poland. The large concentration of sites, especially from the Palaeolithic, is also unheard of. It may therefore be suggested that some artefacts made of chocolate flints found on distant sites, especially those dated to the Late Palaeolithic, can come from the Orońsko mining region. Field research and analyses are still in progress and they will be continued in the upcoming years.

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The social context of Neolithic flint and stone extraction in Britain and Ireland

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Abstract

This research analysed 168 ethnographic studies and 223 global archaeological projects, and was then used to interpret 79 flint mine and 51 axe quarry excavations in Britain and Ireland. This suggests that many extraction sites were special places, deliberately distant from settlements. They followed common practices and assemblages were carefully deposited which the framework suggests reflects technical skill and ritualised practices, but also exclusivity – the sites probably controlled by clans or technical specialists. Previous analyses, particularly of stone axes, demonstrate that many extraction site products travelled long distances, were often unused and deposited in non-settlement contexts. Conversely, artefacts knapped from expedient surface sources are generally discovered in domestic settings, confirming the special nature of extraction sites and their products.

Overall, this statistically-robust ethnographic probability analysis provides a more confident foundation to model the social context of extraction sites through detailed analysis of their setting, composition, structures and assemblages.

Keywords: anthropology, probability analysis, ritualised extraction, social context.

Résumé

Cette recherche analyse 168 études ethnographiques et 223 projets archéologiques à l'échelle mondiale, et a ensuite été utilisée pour interpréter 79 fouilles de minière à silex et 51 fouilles de carrières de production de haches de pierre en Grande-Bretagne et en Irlande. Elle suggère que de nombreux sites d'extraction étaient des endroits spéciaux, délibérément éloignés des habitats. Ces sites relèvent de pratiques communes et les assemblages y ont fait l'objet de dépôts soignés ce qui reflète des compétences techniques et des pratiques ritualisées, mais aussi une exclusivité – les sites étaient probablement contrôlés par des clans ou des spécialistes techniques. Les analyses précédentes, en particulier des haches en pierre, démontrent que de nombreux produits issus des sites d'extraction ont circulé sur de longues distances, n'étaient pas souvent utilisés et ont fait l'objet de dépôts dans des contextes archéologiques non domestiques. À l'inverse, les artefacts taillés à partir de matières premières ramassées de manière opportuniste en surface sont généralement découverts en contexte domestique, ce qui confirme la nature particulière des sites d'extraction et des produits qui en sont issus.

Dans l'ensemble, cette analyse de probabilité ethnographique, statistiquement robuste, fournit une base plus fiable pour modéliser le contexte social des sites d'extraction grâce à une analyse détaillée de leur environnement, de leur composition, de leurs structures et de leurs assemblages.

***Mots-clés** : anthropologie, analyse de probabilité, extraction ritualisée, contexte social.*

1. INTRODUCTION

Prehistoric mines, quarries and their products have often been studied from economic and technological perspectives. Since the 1980s the potential role of ritualisation has been suggested, but is reliant upon a small number of ethnographic analogues which do not encompass the cultural variety even within a single region. The present research has overcome this by using a far larger sample of data than previously attempted, offering a more nuanced understanding of traditional practices. As Hampton (1997, p. 79) has observed, the contiguous communities inhabiting the New Guinea highlands, for example, although superficially similar, '[do] have significant differences' (HAMPTON, 1997, p. 79), including different language groups, different materialities and different social networks. Critically, it is materiality, and particularly stone tools, which is central to the 'ideological reproduction of these communities of forest farmers' (PÉTREQUIN & PÉTREQUIN, 2012, p. 27) – a scenario pertinent to Neolithic Europe.

This research presumes that an interpretive steer can be gained by developing a model from ethnographic analogy based upon the structures within, and social contexts of, the material patterning of practices related to extraction and its products (cf. LEVI-STRAUSS, 1983). To create this model, 168 ethnographic studies were analysed to produce trend data and identify material patterning, which was then tested against 223 global archaeological studies. This research has constructed a near global ethno-archaeological model of extraction practices (TOPPING, 2017) to build upon Binford's (1983) methodologies, and create a reliable interpretive bridge between analogy and archaeological data, particularly where materiality represents metaphorical associations (HODDER, 1982; BOURDIEU, 1990; GODELIER, 1999; FOGELIN & SCHIFFER, 2015). The model uses appropriate social and anthropological theories to explain the content, variability, spatial patterning and context of the archaeological record to enhance understanding of wider social contexts (e.g. GERO, 1989, 1991; GOSDEN & MARSHALL, 1999).

The model uses a 'flow model' approach (cf. SCHIFFER, 1972; FOGELIN & SCHIFFER, 2015), similar to a *chaîne opératoire*, to sketch staged extraction from source identification to exploitation, product manufacture, and product use to final deposition. In addition, the model has the potential to identify why and how extraction site products were objectified to carry narratives, and the ways in which they can structure social networks (HODDER, 1982, 2012) and influence change in society (RATHJE, 1979; MARSHALL, 2008). The ethnography has provided robust information on the contexts of ritualisation within extraction practice and its outcome in society.

2. THE ETHNOGRAPHY OF EXTRACTION

2.1. Storied sources

Many ethnographic extraction sites have storied or ideological associations which incorporate mythology, cosmology and/or community history to legitimise ownership or exploitation, or as explanation of the origin of the raw material. This can underscore objectification and social renewal (BOURDIEU, 1990; GODELIER, 1999; GOSDEN & MARSHALL, 1999; KOPYTOFF, 1986). The ethnography shows that 93 % of sites have storied associations.

Ethnography does not always record the topography of storied sites or the nature of the raw material, but where this data exists, many are locally prominent or distinctive landforms, or comprise unusual deposits visually different from their surroundings in shape, texture or colouration. The extraordinary nature of storied deposits differentiates them from the norm. These differences stimulated storied associations, linking social narratives to cosmology. Such processes objectify raw materials through storied associations (often combined with ritualised extraction), which can then be used to maintain social networks, identity and status.

Storied materials range in scale from the earth as an engendered entity to specific mountains, exposed rock strata, individual boulders, nodules/cobbles to fine minerals. The global scale is seen with the Incas, who viewed the earth as a female entity, Pachamama, but the mountains which contained storied raw materials were male 'lords' (Apu), thus constructing an engendered male – female dichotomy replicating human fertility. These storied raw materials were exploited in caves or mines, which were considered portals to the underworld, and were treated reverentially with idols, offerings, rock art and ritualised practices (DEAN, 2010). Native Americans in the Ozarks also considered caves and rock shelters as origin places and entrances to the underworld, and were exploited for flint clays to produce ceremonial objects, especially figurines (EMMERSON & HUGHES, 2000). Exposures of different raw materials were exploited on the Plains too, such as Minnesota pipestone where surface exposures were quarried in the foreground of a prominent cliff and became mythologised by many tribes (HUGHES & STEWART, 1997).

Storied sites can be individual boulders, such as those of nephrite, considered by the Maori to be fossilised fish which arrived with their first settlers (FIELD, 2012). Smaller still, river cobbles used by many New Guinea communities are associated with supernatural beings or significant ancestors, and can only be processed by ritual specialists. At the Yeineri quarries, Kembe River sources are controlled by the spirit Elogor who has to be appeased before quarrying (HAMPTON, 1997, p. 695). Similarly at the Ngilipitji quarry in Arnhem Land, Aboriginal Australians view quartzite nodules as supernatural Dreamtime 'eggs' which require respectful treatment (BRUMM, 2011).

Fine minerals can also be storied. The Wilgie Mia quarries are part of the Aboriginal Australian Dreamtime where the ochre is believed to be the liver and gall of an ancestor known as Mondong (FLOOD, 1995).

Overall, storied raw materials are generally visually distinctive. Storied associations operate on two levels: (1) those linked to an omnipresent entity and represent that entity's body (e.g. Incas); or (2) a material curated by an ancestor/spirit who has to be appeased to gain access (e.g. Lakota; Dani; Aboriginal Australians). In the latter case, some sites are not considered 'sacred', *per se*, but their link with spirits/ancestors defines them as storied locations (e.g. Yeineri quarries; HAMPTON, 1997, p. 95).

A recurrent theme of storied sites is a correlation between the raw material and a female engendered entity. This female-gendered principle provides a global platform for many ideologies, often manifested by focussing upon specific landscape features for embodiment. Where ancestral or supernatural figures are recorded, female characters also predominate. Consequently, a female-engendered cosmology can be viewed as the ideological affirmation of female fertility and its role in resource provision. The counterpoint to such female engenderment of the raw material is that it is generally adult male extraction teams that create objects which carry a biography, transforming a female-derived material into a symbol of masculine power.

The ethnography suggests that if Neolithic sites were storied locations, they would often see seasonal use, ritualised extraction, craft specialists, supra-regional product distribution (200+ km), some ceremonialism, some rock art/graffiti, and rare burials.

2.2. Ownership, or restricted access

The ethnography records 68 % of sites are owned by individuals, clans or tribal groups. Ownership is characterised as: unspecified = 29 examples; tribal = 22; clan = 15; village = 4; an elder = 3; an individual = 2. Occasionally owned sites are permanently occupied, but most are 1-5 days march from the community.

2.3. Age/sex demographic of extraction site users

The age/sex demographic of site users is predominantly adult male (82 %), followed by mixed gender teams with children (16 %), and a few female-only enterprises (2 %). Children feature in support roles, usually as apprentices. The rare female teams occur among the Konso (Africa) where procurement and tool manufacture is considered a female activity (ARTHUR, 2010), and among the Tiwi (Tasmania) where women mined ochre (PLOMLEY, 1966). Consequently, women do undertake extraction in certain exceptional social contexts (GERO, 1991).

2.4. The evidence for ritualised extraction

Ethnography records ritualised extraction in 92 % of cases. The greatest concentration occurs in North America [32], followed by New Guinea [16], Australia [14], Europe [3] and South America [2], demonstrating that this phenomenon was not geographically-restricted. Ritualised extraction occurs in many distant places and unrelated cultural contexts and is not an isolated response, rather it is a mechanism which connects resource procurement to a cosmology or ideology, centring people in a place.

Ethnography describes preliminary purification rites, prescribed extraction practices, generally on-site artefact production, and often post-extraction renewal rites. These practices leave clear material traces in the archaeological record, and this ethnographic evidence is compared with the archaeological data in Figure 1.

These six indicators of ritualised extraction practices are considered to be the most archaeologically visible, which can deliver a more nuanced interpretation of prehistoric extraction. One of the strongest correlations is between storied locations and the 200+ km distribution of products.

Ethnographic events	***Ethnographic evidence***	***Possible archaeological correlates***
Purification rituals	Sweat lodges ; hearths ; use of substances to purify people and tools	Hearths in or near workings; charcoal in workings
Pre- and post- extraction offerings or rituals	Rock art; curated animal remains; human sacrifices; food stuffs; feasting; consultation of ancestral remains; use of shrines	Rock art near or on-site; placed deposits; pottery; curated animal remains; human remains; structures (e.g. chalk platforms, 'caves')
Ritualised extraction	Extraction tools kept on-site; special tools; substances used to anoint workfaces	Tools left on-site; tool caches; unusual or non-local tools
Rites of renewal	Broken artefacts and production debris returned to site; debitage left on-site; human remains	Broken artefacts and debitage in workings; structured deposits in backfill of extraction site; human remains

Fig. 1 – A comparison of the material evidence of ritualised extraction recorded by ethnography and archaeology.

2.5. Distribution of extraction site products

The distribution of extraction products is a key indicator of ritualised practices and recoverable by archaeology. Ethnography records 64 % of products travel 200+ km from source, 17 % between 100-200 km, and 7 % are found within 100 km of the extraction site. Such patterns demonstrate that cultural value equates with distances transported, and the majority of products move far beyond extraction sites.

If we consider product distributions against six archaeologically-visible features (Fig. 2), the patterning shows that only supra-regional distribution (200+ km) is associated with all six, and again illustrates that the most valued products travelled the greatest distances, often from storied locations. In addition, ritualised extraction was important at all scales of product distribution.

3. THE ARCHAEOLOGY OF EXTRACTION

The ethnographic model derived from 168 case studies was tested against 223 near-global archaeological sites. This analysis was designed to discover common material patterns in the two data sets in a staged, contextual way across extraction, product manufacture, use and discard. The archaeological data showed many correlations with the ethnography, allowing a more cogent modelling of the social context of extraction.

The analysis of the ethno-archaeological model illustrated the following common trends:

1. Distinctive locations
2. Restricted access
3. Ritualised extraction
4. Ceremonialism/burials
5. Rock art/graffiti
6. Supra-regional product distribution

Distance [n = 168]	**Storied sites**	**Owned sites**	**Ritualised extraction**	**Ceremonial use**	**Rock art/ graffiti/ idols**	**Human burials**
200 + km 64 % *[n = 107]*	**85 %** [n = 91 of 107]	**50 %** [n = 54 of 107]	**48 %** [n = 51 of 107]	**49 %** [n = 52 of 107]	**41 %** [n = 44 of 107]	**27 %** [n = 29 of 107]
100-200 km 17 % *[n = 28]*	**50 %** [n = 14 of 28]	**61 %** [n = 17 of 28]	**32 %** [n = 9 of 28]	0	0	0
>100 km 7 % *[n = 11]*	**73 %** [n = 8 of 11]	**55 %** [n = 6 of 11]	**55 %** [n = 6 of 11]	**9 %** [n = 1 of 11]	0	0
No date 12 % *[n = 22]*						

Fig. 2 – Ethnographic product distributions against archaeologically recoverable features.

3.1. The landscape setting of extraction sites

When the model is applied to the landscape setting of extraction sites, several observations emerge which the model would suggest implies they were probably storied locations practising ritualised procurement. Firstly, location was clearly important, with distinctive landforms being preferred (Fig. 3), irrespective of raw material quality. Additionally, visually different raw materials were deliberately targeted, such as Langdale Tuff, Riebeckite Felsite, or coloured flints. The model would suggest these were storied locations.

Fig. 3 – The distinctive dome-shaped summit of the Pike of Stickle axe quarries in Langdale, Cumbria. Photo © P. Topping.

Specific raw material was important: Blackpatch and Harrow Hill mines were deliberately located upon inferior quality flint, despite better deposits nearby (BARBER *et al.*, 1999, p. 24). Clearly here it was the *location* of extraction that was important rather than toolstone quality, a situation paralleled at the Langdale axe quarries where '[t]he larger, more conspicuous outcrops were preferred to those which were easier to reach, even when more accessible sites had equally suitable raw material' (BRADLEY & FORD, 1986, p. 127).

Despite prominent locations, however, the presence of woodland affected visibility (ALLEN & GARDINER, 2012). Although only a minority of sites have provided data, the upland quarries at Creag na Caillich and Langdale/Scafell, the South Downs mines and Grime's Graves (Fig. 4), all produced evidence of woodland. The upland quarries were probably near the treeline, and the mines appear to have been in woodland clearings. Consequently, despite often prominent locations, many sites were hidden by woodland and barely visible (cf. FONTIJN, 2007), which may imply exclusivity, a

Fig. 4 – Grime's Graves flint mines.
Photo © P. Topping.

Fig. 5 – The periglacial stripes at Grime's Graves flint mines, defined by different vegetation.
Photo © P. Topping.

fact supported by evidence of ritualised practices at these sites. In addition to the woodland at Grime's Graves, periglacial stripes surrounding the mines may have also influenced cultural perceptions of the site (Fig. 5).

Rock art/graffiti is an integral part of ritualised extraction for many cultures, and is present at roughly 30 % of archaeological sites. The lack of permanent settlement at archaeological sites would be explained by the model as evidence of taboos preventing domestic activity near extraction, adding to the impression of exclusivity. In addition, long-distance product distributions in almost every archaeological case would suggest evidence of storied locations practising ritualised extraction.

Taken together, the high percentage of sites in prominent locations, or comprising distinctive deposits, provides a strong parallel with the cross-cultural ethnographic trends, and implies that the majority of archaeological sites were also storied.

3.2. Evidence for seasonal extraction

Seasonality can be both a deliberate act and a practical constraint imposed by location and climate. Ethnography documents seasonality in 89 % of cases. The archaeological record has evidence suggesting seasonality or temporary abandonment, comprising wind-blown silts in the workings, stabilised and compacted horizons in backfill, and hearths, debitage, placed deposits, and animal remains on stabilised layers. Circumstantial evidence such as bat skeletons in galleries at Grime's Graves (Pit 1 & Pit 2), proves these sites were open during the winter hibernation period (TOPPING, 2011).

Amongst the British and Irish sites, natural silts, stabilised horizons and assemblages are recorded in 53 % of mines and 33 % of quarries.

3.3. The practice of stone extraction

Ethnography records ritualised practices in 92 % of cases, and of those 94 % were storied locations. The presence of storied associations demonstrates that ideologies and ritualisation were entangled. At times ritualised practices can become obscured. For example, 'functional' deposits of extraction tools left *in situ* at most sites may be material evidence indicating taboos preventing removal (as recorded at the Aboriginal Wilgie Mia mines), rather than simply casual discard.

The ethnography identifies broad trends in ritualised extraction, which are sequential, and follow a *chaîne opératoire* (Fig. 1):

1. Ritualised preparations
2. Ritualised extraction
3. Renewal rites
4. Ritualised closing ceremonies
5. Occasional human burials

The archaeological record contains similar material patterning.

3.4. Ritualised preparations

Ritualised extraction often begins with purification rituals, including prayers, offerings, and rock art/graffiti in or near the sites. Purification uses smoke/steam, prayers at hearths, sweat lodges or burning herbs. The archaeological record contains material evidence suggesting purification activities.

3.5. Hearths/charcoal deposits

Ethnography records the purification of individuals and extraction tools at hearths. Archaeologically, hearths occur in 29 % of mines and 10 % of quarries, with smaller charcoal deposits at 29 % of mines and 30 % of quarries. Examples occur on the floors of Shaft 5 at Blackpatch (RUSSELL, 2001), the Cave Pit at Cissbury (PARK HARRISON, 1877), Pit B49 at Easton Down (STONE, 1933), Pit 21 and Shaft III at Harrow Hill (CURWEN & CURWEN, 1926; HOLLEYMAN, 1937), Pit 1, Pit 2 (Fig. 6), Pit 15 and the 1971 Shaft at Grime's Graves (MERCER, 1981) - none appear to have been used for lighting, cooking or hardening antler picks. A group of hearths was discovered on Floor B at Graiglwyd within the quarry workings (HAZZLEDINE WARREN, 1921), and another was found at Ballygalley Hill upslope from the quarries (COLLINS, 1978). The contexts of these hearths and the lack of domestic activity suggest they were part of extraction practice.

3.6. Offerings

Ritualised extraction was enhanced by accompanying paraphernalia. Archaeological evidence of non-functional material comprises carved chalk objects, pottery, re-deposited debitage and lithics, graffiti, and structures (e.g. chalk platforms). This evidence, alongside preparations at hearths, suggests the deposition of offerings. Examples include a 'shell deposit' and carved chalk object from Shaft 2, Gallery III, Blackpatch (RUSSELL, 2001); a carved chalk ball

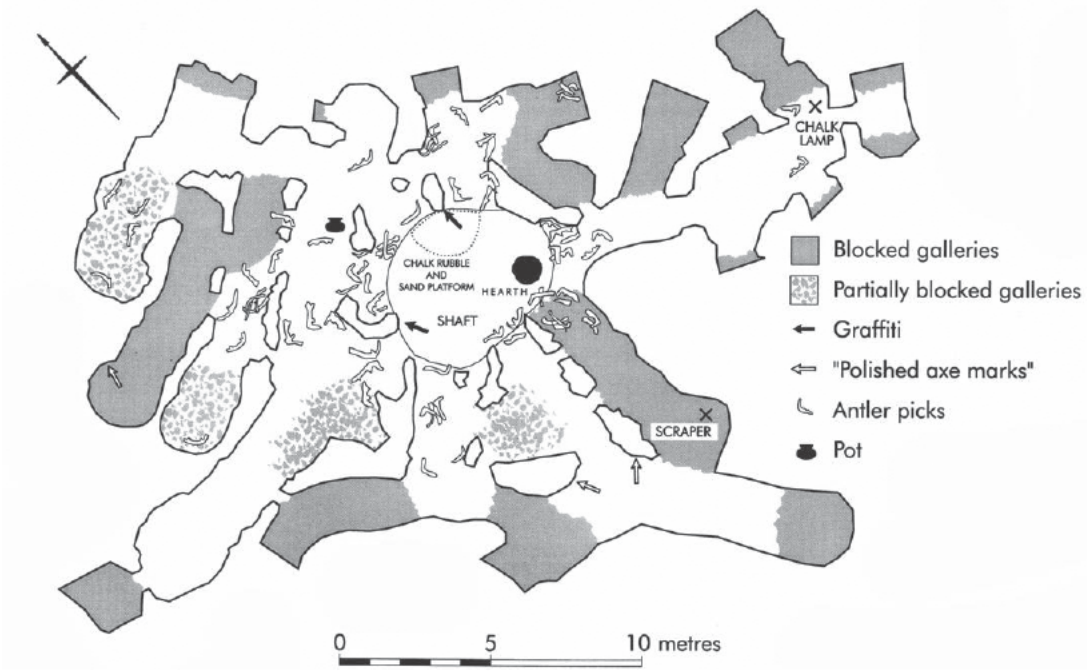

Fig. 6 – Pit 2, Grime's Graves, showing the distribution of assemblages within the mine.
Plan © T. Pearson (after CLARKE, 1915).

from Gallery I and chalk objects and animal bones from the fill of Shaft 7, Blackpatch (PULL, 1932); two ox skulls and other animal remains and four carved chalk objects from Tindall's 1874 Shaft, Cissbury (WILLETT, 1880); a dog skull discovered in Pit B1(A), Easton Down (STONE, 1931); and carved chalk objects and Grooved Ware from Pit 1, Grime's Graves (CLARKE, 1915). The carved chalk objects are clearly not extraction tools, and comprise balls, phalli and inscribed blocks, paralleling ethnographic offerings (Fig. 7).

These assemblages target entry points into the deeper workings, particularly gallery entrances, as in the 1971 Shaft, Grime's Graves, where two internally-decorated Grooved Ware bowls lay on a platform (MERCER, 1981), or graffiti above entrances at Harrow Hill, Cissbury and Grime's Graves (BARBER *et al.*, 1999). The shaft floors thus became a structured arena where hearths, graffiti and placed deposits created a demarcated stage where objects transmitted messages to trigger appropriate actions to maintain cosmological order during extraction.

Evidence for offerings also exists at quarries, including two axehead roughouts placed on a deposit of silt and debitage in the South Scree 'Cave', Langdale (FELL, 1951); the schist disc amongst debitage in the Working Gallery, Beorgs of Uyea, Shetland (SCOTT & CALDER, 1952); and pit deposits buried beneath cairns at Lambay Island (COONEY, 2005).

Fig. 7 – Carved chalk objects from the Cissbury flint mines. Photo © D. Field.

3.7. Rites of renewal

Ethnography documents the return of debitage and rejected artefacts to sites as part of renewal rituals. At archaeological sites this can be inferred from debitage or artefacts discovered in dark, subterranean workings with no evidence of artificial light where tool production clearly did not take place, as at Blackpatch, Cissbury, Den of Boddam, Durrington, Goodland, Grime's Graves, Harrow Hill, and Stoke Down. Renewal would also explain the 300+ axehead roughouts recovered by excavations at Grime's Graves (Gillian Varndell pers. comm.), or the cache of axeheads in Shaft III at Harrow Hill, where 33 'in various stages of manufacture' were discovered (HOLLEYMAN, 1936). The quarries have fewer such deposits, but they do occur at Site 95 (BRADLEY & EDMONDS, 1993), and South Scree 'Cave' (FELL, 1951), both in Langdale.

3.8. Human remains

Human remains are rare at archaeological sites, although excavation bias and taphonomy need consideration; the human remains discussed here are from the mines. Ethnography records burials in 18 % of cases, particularly in Australia and North America. Amongst the Neolithic mines, burials occur at 12 % of sites: 'Barrow' 2, Blackpatch, a small pit contained an adult male inhumation, a chalk object near the skull, and an unrelated skull fragment in the upper fill (PULL, 1932); 'Barrow' 3, Blackpatch, a small pit held two successive inhumations accompanied by lithics and animal bones beneath a 'barrow' of reconfigured mine debris (BARBER, 2005); the Skeleton Shaft at Cissbury, contained a female skeleton positioned head down, 0.76 m above the shaft floor, alongside animal bones (LANE FOX, 1876); Shaft VI, Cissbury, an adult male skeleton lay mid-way down the shaft surrounded by chalk blocks, lithics and a carved chalk object (PARK HARRISON, 1878); in Shaft 27, Cissbury, an adult female skeleton was discovered on the lower shaft fills with two chalk objects and a 'fossil-like worm' (TOPPING, 2005); and in Pit 2, Grime's Graves, a disarticulated skeleton lay mid-way down the shaft, juxtaposed with animal bones and lithics and below a series of hearths (CLARKE, 1915).

Body parts occur at 10 % of archaeological sites. Examples include: Shaft 4, Blackpatch, where an adult's femur and child's mandible were found (RUSSELL, 2001); Shaft 6, Church Hill, a fibula was discovered (RUSSELL, 2001); Pit 1, Grime's Graves, the shaft contained a human skull wedged between chalk blocks 5 cm above an ox bone (CLARKE, 1915); and the lower fills of Pit 3, Grime's Graves, produced a pick made from human bone from Early Bronze Age workings (LONGWORTH & VARNDELL, 1996).

Overall, the human remains suggest formal or casual burials designed to link the dead to the raw material, as suggested by ethnography. Burials and body parts are predominantly found in the lower half of shafts, or beneath mounds of mine debris. However, by the Early Bronze Age at Grime's Graves burials are absent, suggesting a shift in practice, although a human femur was used as a pick in Pit 3 (LEGGE, 1992; LONGWORTH & VARNDELL, 1996), demonstrating the deliberate use of human remains as extraction tools. This occurred during a period when metalworking was first introduced, and society moved away from communal beliefs to greater individualism and social inequality.

If the predominantly female remains recovered from the mines represent site workers, then unlike the male teams of ethnography, the archaeological sites suggest that mixed gender teams, possibly with children (e.g. child's mandible, Shaft 4, Blackpatch), operated on the South Downs; at Grime's Graves and the upland quarries it is less clear. The presence of human remains parallel practices recorded at causewayed enclosures, long barrows and henges.

3.9. Graffiti/rock art

Graffiti/rock art is a feature at 14 % of mines and 2 % of quarries. Ethnography suggests this may be part of ritualised preparations to legitimise procurement, satisfy cosmological concerns, and provide an arena for offerings.

This art targets access routes, observation points, and creates cultural or ideological boundaries. In the mines it occurs above gallery entrances at entry points to the deeper workings, and rock art panels on valley floors provide views to the upland quarries. In addition, portable art such as inscribed chalk blocks at the mines, and a stone plaque from Graiglwyd axe quarry (HAZZELDINE WARREN, 1921), hint at a role for portable art in extraction practice.

3.10. Site abandonment

Site abandonment often follows episodic sequences of backfilling, paralleling trends in ethnography where 33 % of cases documented post-extraction ceremonialism. The archaeological evidence of backfilling events comprises stabilised surfaces, natural silts and assemblages. Such evidence occurs at 53 % of mines and 33 % of quarries, suggesting prescribed abandonment practices, and is seen at the mines at Blackpatch, Church Hill, Cissbury, Easton Down, Harrow Hill, Goodland, Grime's Graves and Stoke Down, and the quarries at Creag na Caillich, Graiglwyd, Lambay Island, Langdale and Mynydd Rhiw. The chronology of staged backfilling spans the Neolithic and Early Bronze Age, indicating a long-lived tradition.

Abandonment at mines was generally episodic, following the sequential backfilling of the galleries, and progressed in stages up the shaft. Each abandonment event was often accompanied by cultural objects, human and animal bones, and/or hearths (Fig. 8). For example, Shaft 27, Cissbury, a minimum of 12 deposits filled the shaft (TOPPING, 2005); the 1971 Shaft, Grime's Graves, comprised at least 6 backfilling events, interspersed with *c.* 13 phases of stasis represented by natural silts (MERCER, 1981). These sequences prove that some mines remained open as arenas for post-extraction ceremonialism, mirroring ethnographic practices designed to appease cosmological concerns.

To summarise, this evidence suggests that the archaeological record strongly parallels the ethnography, and implies that ritualised extraction probably occurred at most, if not all, sites mentioned above. The analysis found that the commonest themes at the mines are: distinctive locations; debitage/lithics in the workings; stabilised horizons and hearths in the workings; tools abandoned in workings; and

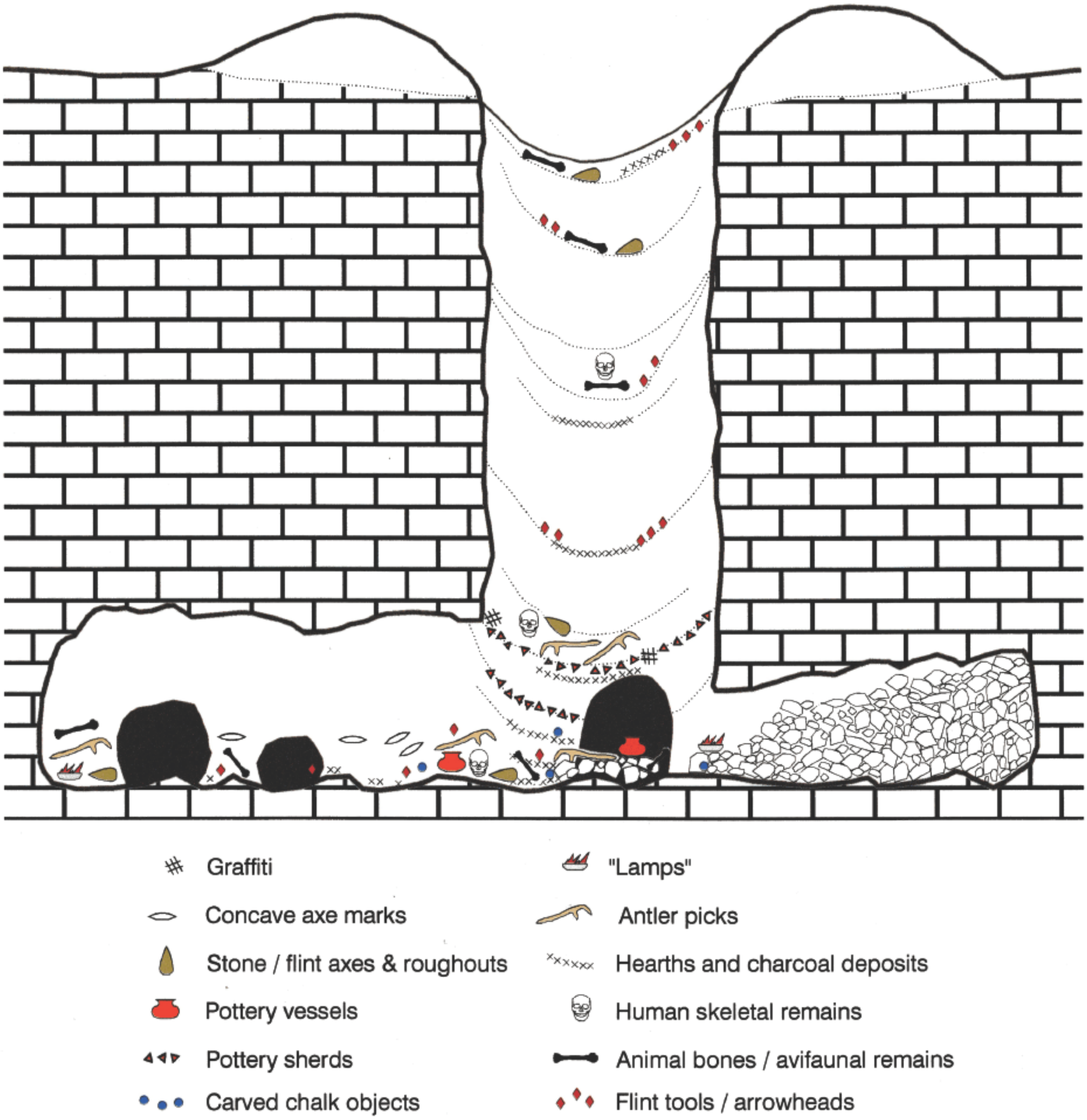

Fig. 8 – The spatial and temporal distribution of assemblages in the British flint mines. Diagram © P. Topping & T. Pearson.

deposits of disarticulated animal remains. At the quarries the commonest themes are: distinctive locations; debitage/lithics in workings; rock art/graffiti within 5 km of the site; and supra-regional product distribution (200+ km). These comparators would suggest that where most, or all, occur, then we can infer storied locations practising ritualised extraction to produce valued products for extensive distribution.

3.11. The chronology of extraction

The chronology of these sites and practices (Fig. 9) spans the Early Neolithic at the South Downs and Wessex Groups of mines (WHITTLE *et al.*, 2011) to the Late Neolithic/Early Bronze Age at Grime's Graves (HEALEY *et al.*, 2014), Den of Boddam (SAVILLE, 2005) and Hambledon Hill (MERCER & HEALY, 2008). The quarries are an earlier Neolithic phenomenon, with only Creag na Caillich exploited in the Late Neolithic/Early Bronze Age (EDMONDS *et al.*, 1992).

This chronology combined with the immediate introduction of galleried mines, proves an important point - extraction practices

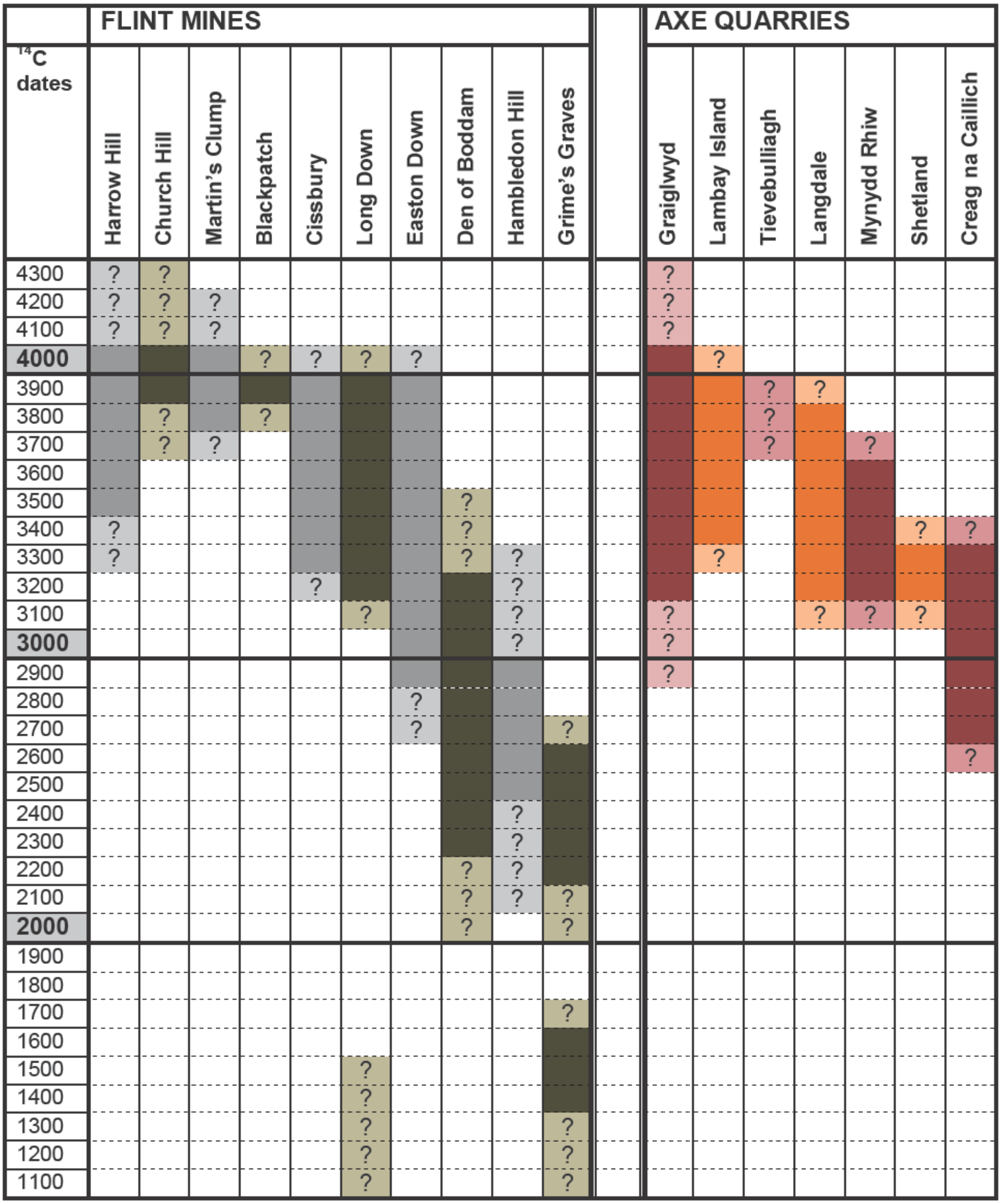

Fig. 9 – The relative chronology of axe quarries and flint mines based upon crude radiocarbon dates.

existed *before* the introduction of Early Neolithic activity in southern England, as demonstrated by the European radiocarbon chronology. This pre-existing knowledge drew heavily upon technical expertise from Europe – shaft and gallery mining was not an *ad hoc* activity, it required geological knowledge and technical skill. In addition, certain material practices were repeatedly followed during extraction, particularly assemblage deposition in specific locations. This shows that extraction practice followed a shared ideology brought to Britain and Ireland from adjacent areas of Europe as part of 'being' Neolithic.

Neolithic practices may have entered southern England via several routes, including the Thames Estuary. As observed, the South Downs mines, and possibly the Wessex Group, were among the first constructions in a landscape used by mobile groups with shifting mixed farming, and a reliance on wild resources. It would take another 100-300 years before communal monuments appeared (e.g. long barrows, causewayed enclosures) to anchor communities to other places for different social imperatives. The Graiglwyd, Lambay Island, Langdale and possibly Tievebulliagh quarries were exploited at roughly the same time. Most have one thing in common – they are close to, or visible from, the sea. This suggests the Neolithic transition and the introduction of mining resulted from sea travel skirting southern Britain and the Irish Sea, lent weight by the early dates from the South Downs, Graiglwyd, Langdale and Lambay Island.

One possible point of origin was the Paris Basin. Here flint mining not only appeared roughly 4-500 years earlier than in Britain and Ireland, *but* the Paris Basin flint mines were also one of the first Neolithic site types to appear in that landscape too, thus paralleling the sequence in Britain (GILIGNY, 2011; GILIGNY & BOSTYN, 2016).

The aggregated ethnography builds upon the work of Bradley, Edmonds, Cooney, Whittle and others, to provide a more nuanced perspective of extraction sites. Such documented processes are fundamental to reconstructing practices and outcomes. The fact that many extraction sites in Britain and Ireland lie beyond the limits of settlement and ceremonial monuments, suggests exclusivity and probably restricted access - with control by tribes, clans or a technical elite. The research of Allen and Gardiner (2012) demonstrates that many sites were hidden in woodland, adding to their liminality. A final factor which suggests sites were considered special places is the fact that nearly all had more accessible sources of raw material locally but these were ignored in favour of those from more difficult but significant locations.

Ethnography has provided useful insights into the cosmology of extraction sites. A recurrent theme is the presence of female deities, creating male (quarry teams) and female (supernatural entities) roles, suggesting procurement may have symbolically mirrored human procreation. Consequently, a female-engendered cosmology may be an ideological affirmation of female fertility in relation to toolstone. Conversely, it is often male extraction teams who work the female-engendered resources and create objects which transform a female derived substance (e.g. toolstone) into a symbol of male power.

Some ethnography cites extraction site products as 'profane' tools initially, which can be ritually transformed into 'sacred' objects at

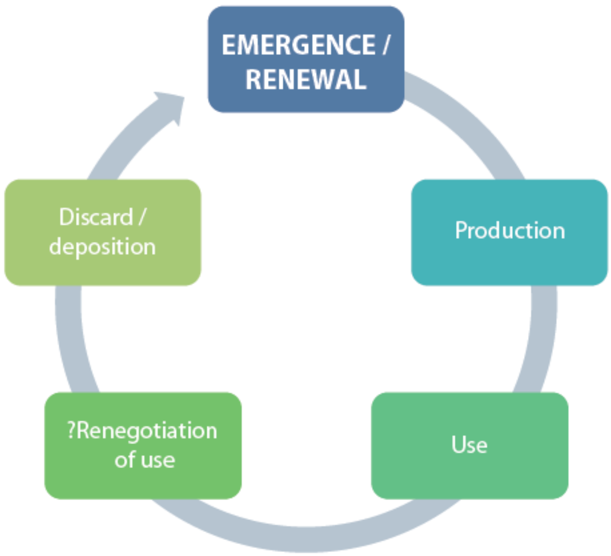

Fig. 10 – The ethnographic cycle of lithic procurement from emergence to discard, including potential conversion of use/value. Diagram © P. Topping.

certain times to fulfil ceremonial or social obligations (Fig. 10). In addition, some objects convey sacredness but *not* wealth, a key finding which may be seen archaeologically by the fact that only rarely are multiple axeheads found in graves as demonstrations of inferred 'wealth'.

A strong ethnographic correlation exists between long-distance movement (200+ km) of extraction site products and ritualised extraction in 64 % of cases, which compares with 60 % in the global archaeological data. This lends security to the interpretation of product outcomes from ritualised extraction practices.

4. CONCLUSIONS

Overall, this analysis suggests that many prehistoric extraction sites were special places used in ritualised ways. Ethnography shows ritual permeates even mundane activities in many traditional societies, and the assemblages and non-functional deposits in many Neolithic extraction sites suggest similar practices occurred during their use. Consequently extraction must have been entangled with controls and rituals designed to counter inherent dangers, ensure success, and maintain the status of the site, the miners and their products. Final deposition of many extraction site products was in non-domestic contexts in contrast to products made from expedient sources, demonstrating that extraction site objects were enmeshed in a web of procedure, transaction and social performance. As Edmonds (1993) has noted, if the Early Neolithic did not see a 'wholesale economic transformation' with extensive woodland clearance and widespread agriculture, then other explanations for the proliferation of flint and stone axeheads is needed, particularly unused examples. Consequently, it is difficult to escape the conclusion that the axehead became a widespread *leitmotif* during the earliest Neolithic in Britain and Ireland – as in Europe.

The extensive distribution of many stone axeheads throughout Britain and Ireland which were often deposited broken or burnt, or buried in hoards, demonstrates a deeper significance than functional tools. As Fontijn (2007, p. 77) observed, '[p]articular objects – and the ideas that they stand for – can become a central memory paradoxically precisely because they were destroyed or removed in a specific ceremony ... [creating] remembrance by removal.'

The cultural value of Cumbrian Group VI axeheads, for example, is seen in Ireland where 23 % were discovered in rivers and 20 % in bogs, demonstrating their importance in wetland deposition - even higher percentages of indigenous Irish axeheads are found in these contexts (COONEY & MANDAL, 1998). In parallel, many Antrim Group IX axeheads were recovered from various contexts in Britain, showing the value of exotic objects to communities on both sides of the Irish Sea. Similarly, the South Downs mines follow this trend, with axeheads from the mines recorded on the adjacent coastal plain mostly unused and carefully curated (GARDINER, 1990).

The physical and metaphysical challenges of extraction objectified raw materials, making them 'pieces of places' as Bradley (2000) has suggested, resonant with symbolic power. The physical dangers are typified by the precipitous Top Buttress quarries on Pike of Stickle, Langdale, for example, or at the Creag na Caillich quarries, and off-shore sources such as Lambay and Rathlin Islands involved challenging sea travel. Such logistical difficulties required mediation with natural and supernatural forces.

Mediation is most readily seen in the patterned evidence of ritualised extraction in most mines. Human remains are found only in shaft fills and not within galleries; pottery only occurs in shaft fills at Grime's Graves and the Irish quarries at Ballygalley Hill (COLLINS, 1978) and Goodland (CASE, 1973); hearths were only placed on shaft floors or shaft fills; lithics and debitage occur in various contexts throughout the workings; and graffiti is found above gallery entrances.

Ethnography suggests that many distinctive prehistoric extraction sites may have been engendered or mythologised as a means of explaining the origins of the cultural landscape and humankind's place within it. At Grime's Graves, periglacial stripes visible on the ground surface create an unusual striped patterning around the mines. Similar stripes found at Stonehenge (a broadly contemporary monument), influenced the winter solstice alignment of the site and Avenue.

The skyline location of many sites placed them symbolically between the earth and the sky, which in a layered cosmology may have situated them at an interface of the surface world, the underworld and the heavens. Isolation and liminality would have enhanced such locations. As Cooney (1998) has observed, the fact these sites visibly altered the landscape created a monumentality that embedded them psychologically into the cultural landscape.

Towards the end of the Early Bronze Age ritualised practices diminished at Grime's Graves, and shaft mining changed to pit extraction, and bone picks replaced antler. At the Creag na Caillich quarries, secondary extraction changed products to perforated axeheads, and the pits at Den of Boddam provide little evidence of ritualisation. This realignment of extraction practice occurred when Arreton and Acton metalworking traditions were well established, cremations in Urns took place, and Deverel-Rimbury traditions eclipsed Wessex 2, creating a period of social transformation which appears to have ended the ideological need for ritualised extraction practices.

4.1. Stone extraction and identity at the beginning of the Neolithic

This research has shown the earliest extraction sites are located near the sea, which demonstrates their pivotal role in Neolithisation as they were some of the first Neolithic constructions. Consequently, extraction sites were deeply involved in the creation of identity and becoming Neolithic. Their location suggests that prospection and stone procurement was undertaken along the coastline, with the axe quarries ranged around the Irish Sea and the flint mines overlooking the Channel, arguably fossilising two Neolithic routes to Britain and Ireland.

Archaeology records that communities in Britain, Ireland and Europe followed a general tradition of extraction – with common practices. This implies that ritualised extraction had its foundations in a pan-European social phenomenon which was later adopted in Britain and Ireland, with some modifications reflecting an emerging cultural diversity. It was the role of the most abundant implement from the extraction sites, the axehead, which became truly transformative in society in a variety of ways. As Allen and Gardiner (2012) have observed 'the inherent symbolism of producing from the ancient forests the very means of cutting them down' produced a paradigm shift. Communities no longer relied upon the unpredictability of fire or natural events to create forest clearings as in the preceding Mesolithic, they now took direct control over nature and began to transform their cultural landscape with the axe. Consequently, this implement, which was emblematic of control over nature, became adopted as a symbol of control in society and was embedded in various social institutions and carefully curated, becoming as Brumm (2011) has characterised them – '*power tools*'. Tools that had emerged from ritualised performances at charged, storied locations on the very edges of the cultural landscape.

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Basalt axe production sites in the Bakony Mountains (Hungary)

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Abstract

The Bakony Mountains is one of the prehistoric 'industrial' centres of Hungary. Siliceous raw material exploitation sites are known and published from the area. Recent study on polished stone artefacts of the region resulted in the recognition of intensive artisan activity on Late Neolithic sites of the area in respect of local basalt resources. So far, the best evidence is known from survey material from the sites of Zirc, Porva and Pénzesgyőr, from the collection of E. Wolf; half products, technological tool types and fabrication debris, various hammerstones and polishers. The publication of the surface collected evidence of polished stone artefact workshops will hopefully support the systematic study of these important sites.

Keywords: Hungary, polished stone artefacts, basalt, half-products.

Résumé

La montagne de Bakony est l'un des centres « industriels » préhistoriques de Hongrie. Des sites d'exploitation des matières premières siliceuses y sont connus et publiés. L'étude récente d'outils en pierre polie issus de cette région a permis la reconnaissance d'une intense activité artisanale sur les sites du Néolithique récent en relation avec les ressources locales de basalte. Jusqu'à présent, les indices les plus probants proviennent de la collection de E. Wolf, récoltée par prospection sur les sites de Zirc, Porva et Pénzesgyőr, des préformes, différents types d'outils, des déchets de fabrication, ainsi que de nombreux percuteurs et polissoirs. La publication du matériel composant cette collection de surface et témoignant de l'existence d'ateliers de fabrication d'outils polis permettra, on l'espère, l'étude systématique de ces sites importants.

***Mots-clés**: Hongrie, outils en pierre polie, basalte, préformes.*

1. Introduction

In course of a preventive excavation on motorway No 8 in the outskirts of Veszprém (2010), a special depot find was located in a pit. The depot comprised nine basalt axe preforms and blocks to be prepared for polished stone axes. The interesting find assemblage was published by Judit Antoni (2012).

Parallel finds to the preforms and half products were searched for to establish date and context of this find assemblage. The quest for analogies coincided with another program for polished stone artefacts, trying to locate greenstone (basically, jadeite and related rocks) of long-distance origin within the framework of JADE2 project lead and organised by Pierre Pétrequin and Estelle Gauthier (PÉTREQUIN *et al.,* 2017). In connection with these two projects we came across the evidences collected by and methodically stored in the private collection of Ernő Wolf (Zirc).

2. The collection of Ernő Wolf

Ernő Wolf is a long-time collector of antiquities, especially prehistoric finds in the vicinity of the town Zirc and its environs. He contributed to the topographic surveys of the region and took part in a number of excavations in Transdanubia. Part of his collection was described by archaeologists dealing with this territory (BIRÓ & REGENYE, 2003; REGENYE, 2000). From the rich surface collection of finds he gathered throughout the years, this paper is concentrating on polished stone artefacts – more specifically, basalt axe preforms and half-products.

2.1. Information on the sites involved

Part of the collected material comes from sites noted and described first in the framework

SITE NAME	SITE	MRTNR	MUS	AGE	Culture	Nr. of polished stone artefacts*
Porva - Ménesjárás II.	612	MRT IV 67/W3	WE	LN, B	Lengyel Culture	3 (3)
Porva - Ménesjárás I.	613	MRT IV 67/W2	WE	LN	Lengyel Culture	9 (6)
Porva - Ménesjárás III.	614	MRT IV 67/W4	WE	LN, B	Lengyel Culture	7 (5)
Porva – Pálinkaház-puszta	615	MRT IV 67/10	WE	B	Late Bronze Age	4 (3)
Porva - Győri úti rétek	616	MRT IV 67/3	WE	LN, B	Lengyel Culture + BA	21 (19)
Porva szórvány	617	unknown (purchased)	WE	unknown	unknown	1 (1)
Tés - Kistés	618	MRT IV 74/2-3	WE	LN	Lengyel Culture + Roman Period +- Mediaeval Period	3 (2)
Jásd - Récsenyi hegy	619	MRT IV 35/4	WE	LN	Lengyel Culture + Roman Period	3 (2)
Nagyesztergár - Purgly major	620	MRT IV 52/2A	WE		Roman Period	2 (2)
Olaszfalu - Felsőpere, Csicsóvölgy	621	MRT IV 60/W3	WE	LN	Lengyel Culture +BA, Roman Period, Avar, -Mediaeval Period	2 (2)
Borzavár – Alsótündér-major I.	622	MRT IV 18/5	WE	LN, B	Lengyel Culture + BA	2 (2)
Borzavár - Bocskorhegy	623	MRT IV 18/3	WE	LN, B	Lengyel Culture + BA	3 (3)
Zirc - Királypatak II. - Szélesrét	624	MRT IV 81/W4	WE	LN	Lengyel Culture	3 (3)
Zirc - Aklipuszta III.	625	MRT IV 81/W2	WE	B	Urnfield Culture	5 (4)
Pénzesgyőr-Halastóárki dűlő I.	626	MRT IV 66/6	WE	LN, B	Lengyel Culture + BA	6 (6)
Zirc - Királypatak I.	627	MRT IV 81/W1	WE	LN	Lengyel Culture	76 (69)
Pénzesgyőr-Halastóárki-dűlő III.	628	MRT IV 66/W1	WE	LN	Lengyel Culture	110 (98)

* in brackets, number of associated finds, e.g., raw material blocks and tools of production

Fig. 1 – Polished stone tools and related artefacts from the Wolf Collection (Zirc environs).

of the topographic survey of Hungary. It is noteworthy that the complete archaeological topographic survey of Hungary was initiated by the researchers of the Archaeological Institute of the Hungarian Academy of Sciences in the 1960s. Veszprém County was the first among the 19 Hungarian territorial units (counties) where complete topographical surveys were made. The results were published by smaller regional units, i.e. 'districts', in Hungarian, '*járás*' (MRT I-IV). This regional unit was later abolished (1983) and recently re-installed (2012), see https://upload.wikimedia.org/ wikipedia/ commons/d/d3/ Townships_%28districts%29_of_Hungary.png

This process was not completed as yet. Veszprém County is certainly one of the regions where archaeological topography is completed to a certain degree. Completion to the data of the sixties was published from the Pápa district

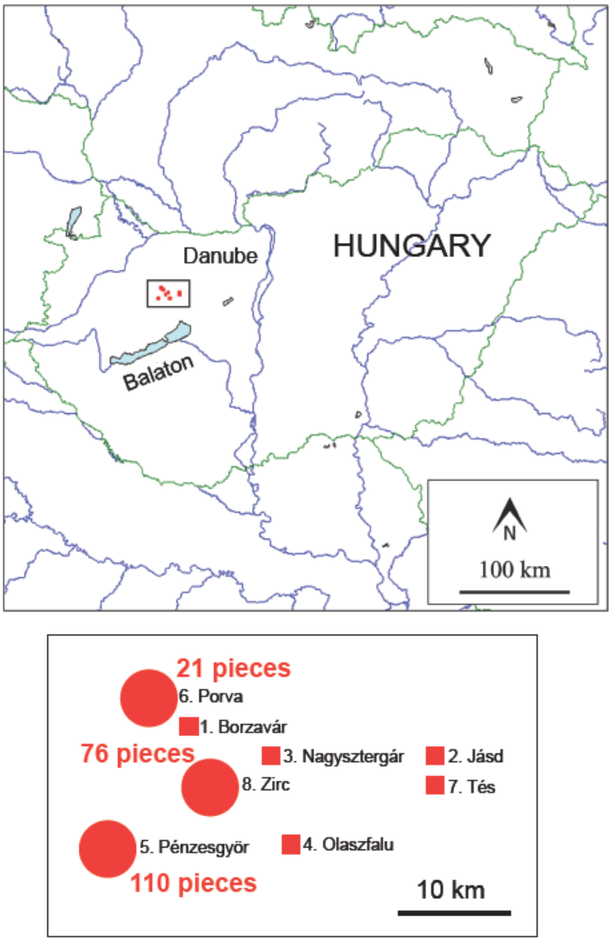

Fig. 2 – Sites with polished stone tools from the Wolf Collection mentioned in the text.

so far (ILON, 1995). The sites included in the topographical surveys are marked with the topographical reference number, starting with 'MRT' (MRT: Magyar Régészeti Topográfia, i.e., Hungarian Archaeological Topography).

The other sites investigated are the result of the personal fieldwork by E. Wolf. These sites are marked 'W' after the number used in the MRT volumes for denoting the locality (Fig. 1, Fig. 2).

Almost all sites contained, typically basalt, polished stone axes and/or preforms. Raw material lumps were found at three sites (17 percent of sites), technological pieces (flakes, chips) of axe production were recorded on five sites (29 percent of sites), and tools for making polished stone tools (hammerstones, polishers) were found at five sites (29 percent of sites). We must remember that these sites are merely surface collected materials without exact context.

The most productive sites in respect of polished stone tool production were Pénzesgyőr, Porva and Zirc-Királypatak (Fig. 3).

The main features of these sites can be summarised in the following.

2.2.1. Zirc- Királypatak I (81/W1)

47°14'N, 17°52' E, 445 m a.s.l.

The site is located on a NNW-SSE directed hillside, bordered by stream valleys. Late Lengyel settlement features can be observed on a patch of land approximately of 300 x 150 m extent.

Seven to eight find concentrations were observed, in a distance of 30-60 m from each other.

Archaeological finds:

Pottery: Many Late Lengyel fragments in bad state of preservation. Special forms: Spindle whorls and pottery with imprints of woven bulrush.

Chipped stone artefacts in large quantity, raw material blocks, cores, tools and production debris. Raw material is typically radiolarite, mainly mustard yellow (Úrkút-Eplény) type, followed by red and brown (Szentgál, Hárskút)

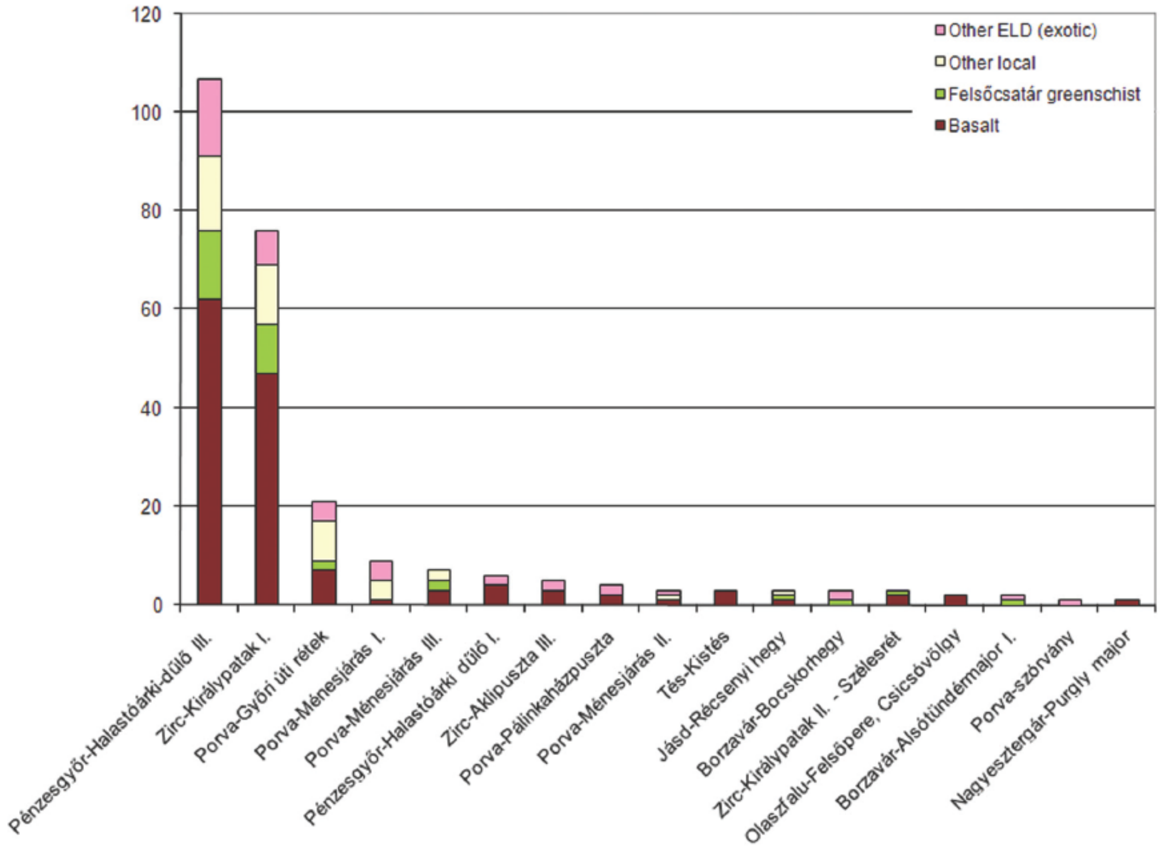

Fig. 3 – Main raw material type group distribution of the studied material.

radiolarite and inferior quality local chert (BIRÓ & REGENYE, 1995, 2003).

Polished stone artefacts: More than 70, mainly basalt and greenschist axes and chisels. Basalt raw material blocks and axe preforms in large quantities.

Grinding stones and polishers: Typically made of basalt tuff and various sandstones including very large pieces (e.g., 30 x 40 x 20 cm, 34 kg).

Hammerstones: Large quantities of worn quartzite percussion tools. On the southern side of the settlement, such large quartzite pebbles crop up *in situ*.

Daub fragments occurring in patches, some with prints of tree-branches.

No animal bones or bone tools were found on the settlement.

2.2.2. Pénzesgyőr- Halastóárki-dűlő III - Köves hegy alja (66/W1)

47°13' N, 17°48' E, 400 m a.s.l.

In the middle of the hill-top sloping N to S from the Köves hill to the Gerence stream a 480 x 250 m extent area with traces of a Late Lengyel period settlement. Concentration of finds can be observed at 10-12 points located at a distance of 40-90 m to each other.

Archaeological finds:

Pottery: Many fragments of Late Lengyel pottery in bad state of preservation. Special forms: Ladle and pottery with imprints of woven bulrush.

Chipped stone artefacts: In large quantity, raw material blocks, cores, fabrication debris and finished tools. Most of them made of dark brown (Hárskút type) radiolarite, followed by red and mustard yellow (Szentgál, Úrkút-Eplény type) radiolarites with other inferior quality local chert.

Polished stone artefacts: More than 90 pieces of polished stone artefacts made of basalt and greenschist mainly. Basalt is present in the form of raw material blocks and axe preforms as well.

Grinding stones and polishers: Relatively large amounts made of basalt tuff and various grain size sandstones, both fragmented and complete pieces.

Hammerstones: Large basalt and quartzite pebble specimens with intensive traces of use.

No daub or animal bone / bone tool was found so far on the settlement.

2.2.3. Porva group of sites

Porva- Győri úti rétek (MRT 67/3), 47°18' N 17°48' E 368 m a.s.l.
Porva- Felsőerdő (MRT 67/5), 47°18' N 17°48' E 385 m a.s.l.
Porva- Ménesjárás I-W hill N part (67/W2A1), 47°18' N 17°46' E 394 m a.s.l.
Porva- Ménesjárás II-Középső domb (67/W3), 47°18' N 17°47' E 384 m a.s.l.
Porva- Ménesjárás III-Keleti domb (67/W4), 47°18' N 17°47' E 387 m a.s.l.

To the NW of the village Porva, on a 2 x 2 km large area around the headwaters of the Hódos stream, on hilltops facing S traces of several small Late Lengyel settlements were located. Their extent ranges between 50-80 x 50-150 m.

At Ménesjárás I and Ménesjárás II most of the observed settlement patches are of Late Bronze Age.

Concentration of finds can be observed at several places, 20-50 m from each other.

Archaeological finds:

Pottery: Relatively few and small shards in bad state of preservation. Apart from some characteristic details (rim, handle, knobs etc.), some special pieces (ladle, spinning whorl, woven bulrush imprints) can be found.

Chipped stone artefacts: Mainly radiolarite, in relatively low number, typically finished tools. The raw material is varied, mainly of inferior quality.

Polished stone artefacts: Around a dozen axes of basalt and greenschist were found, basalt raw material only at Porva- Ménesjárás I. There were no preforms observed.

Grinding stones and polishers were found only at some of the sites. Hammerstone: One piece as Porva- Győri úti rétek.

No daub, animal bones or bone tools have been found so far.

2.3. Polished stone tools on the sites in the Wolf Collection

In the current study we did not aim at investigating the total collected material, only items related to – or possibly related to – polished stone tool production were studied.

The characteristic raw materials used were basalt, greenschist, sandstone and quartzite (Fig. 3).

3. Polished stone artefacts in the Wolf Collection: Technical solutions for the procurement of lithics

3.1. General features

Field survey for lithics in woodlands, leaf litter or even in plough land is a difficult task. Only a trained eye will know artefacts from 'simple stones', especially in the case of tool preforms and production debris, with or without traces of tool shaping. Museum collections rarely own such pieces and this is far not by chance. Till very recent times, even archaeologists did not recognise such forms or simply ignored them. The depot find of Veszprém-Kádárta (also known as Gelemér or Litér junction) is a break-through in this respect (ANTONI, 2012). Found in course of authentic excavation, a set of axe preforms could be documented (and published) that could facilitate the recognition of similar assemblages.

Another specific aspect of the basalt tools and preforms of the Wolf Collection is the thick yellowish-grey patina formed on the surface, hiding them even better on the soil surface.

The recognition of the pieces arriving to the settlement as specific raw material for further processing is often revealed only by their non-local character. Traces of processing, forming blows to get preforms can be recognised relatively easily. Polished surfaces stand out by their smoother character. Fresh injuries stand out as darker scratches or fractures.

Sawing the raw material for cutting can be observed rarely (see Fig. 7:4 and ANTONI, 2012. fig. 5), probably using a wooden plate saw.

Traces of drilling are more obvious - partly because the circular wall of the drill holes were filled with sediment preserving the surface better.

In case of a well documented excavation, the quantities of fabrication debris can be much better observed than simple field surveys (e.g. BIRÓ, 1992, Aszód-Papi földek) and compared to the total lithic industry of the site (BIRÓ,

Fig. 4 – Basalt raw material artefacts.

1998); complete publication of the Aszód lithics is in preparation of the site monograph (BIRÓ, 2012 manuscript).

In this study we cannot aim at presenting the complete lithic assemblages of the sites presented; only the forms related to polished stone tool production are presented, typical for the region (Zirc environs) and the technical solutions characteristic of the Lengyel Culture.

On the largest settlements localised (Pénzesgyőr, Porva, Zirc-Királypatak) it is evident that the non-local basalt raw material was locally processed by active tool-making procedures. On the sites we can locate all phases of the '*chaîne opératoire*' reflecting the course of polished stone artefact production. In the following we will present the process by the help of characteristic forms and stages.

3.2. Examples of polished stone artefact production in the Wolf Collection

3.2.1. Natural, unworked raw material forms (Zirc-Királypatak I. 81W/1/32; Fig. 4:1*)*

The typical polygonal columns of the basalt 'organs' leant an easy choice for collecting raw material. Our specimen is a flat elongated fragment with triangular section probably selected to make an axehead. Dimensions: l: 22 cm, w: 7.2 cm, h: 2.3 cm, weight: 887 g.

3.2.2. Tested blocks and flakes

The base forms were selected and tested, most probably, on the geological site of the raw material and transported to the settlements for further processing. Cutting of the unwanted mass resulted in better transport and, at the same time, could reveal possible flows and inclusions in the raw material. Characteristic examples include Fig. 4.2, Zirc-Királypatak I. 81W/1/36, dimensions: l: 11 cm, w: 8 cm, h: 1.7 cm, weight: 286 g or Fig. 4.3, Pénzesgyőr 66W/1/21, l: 7 cm, w: 5.3 cm, h: 4.8 cm, weight: 254 g.

On the selected pieces we can typically observe the surface of the detachment of the flake but they also preserved natural fracture surface. The Zirc specimen was also tested for polishing: The protruding ridge was worked on a flat, wide surface. The traces of polishing are poor but visible and can be distinguished from the natural fracture surface.

Both pieces would be suitable for the production of small axeheads.

The flake from Zirc-Királypatak, 81/W/1/39 Fig. 4.4, dimensions: l: 11 cm, w: 6.2 cm, h: 2.2 cm, weight: 235 g was probably collected because of its form to serve as axehead. Conchoidal fractures can be observed on two sides rendering the piece to small or 'twisted' for the original idea but it was still preserved for potential use for a smaller chisel.

Another flake from Pénzesgyőr (66/W/1/70, Fig. 4.5, dimensions: l: 16.8 cm, w: 4-8 cm, h: 3.2 cm, weight: 596 g shows an adze form: Similar to the previous piece, it cannot be considered a proper preform because it is not really suitable and would prevent the production of a real tool. We can classify these pieces as 'trial forms' where, during the tool making process, they were finally rejected.

3.2.3. Half-products and preforms

Preforms proper prepared for polishing were formed by percussion technique. At Pénzesgyőr we find several such forms: 66/W/1/05, Fig. 5:1, dimensions: l: 18.2 cm, w: 6.5 cm, h: 4.8 cm, weight: 759 g and 66/W/1/09, (adze-pick preform), Fig. 5:2, dimensions: l: 18 cm, w: 5.5 cm, h: 4 cm, weight: 591 g as well as the piece 81/W/1/10 from Zirc (pick), Fig. 5:3, dimensions: l: 18.5 cm, w: 5.5 cm, h: 3 cm, weight: 510 g. These preforms represent tool types from the Early Copper Age partly influenced by the new metal (copper) picks and as such can be considered as the closest analogies of the Veszprém-Kádárta depot find (LDM 49.9780.583.4 and 49.9780.583.2; ANTONI, 2012, figs 9, 15).

Also from Pénzesgyőr the chisel preform 66/W/1/25, Fig. 5.4, dimensions: l: 7.8 cm, w: 5.4 cm, h: 3.3 cm, weight: 232 g stand for half-products of an earlier phase of the Lengyel Culture.

3.2.4. Finished tools

Most of the polished stone artefacts collected are different axe, hatchet, hoe and chisel types formed with polishing on suitable form blanks forecasting in their detached form the artefact planned.

Characteristic forms presented here include, from Porva, the hatchet 67/W/4/4, Fig. 6:1,

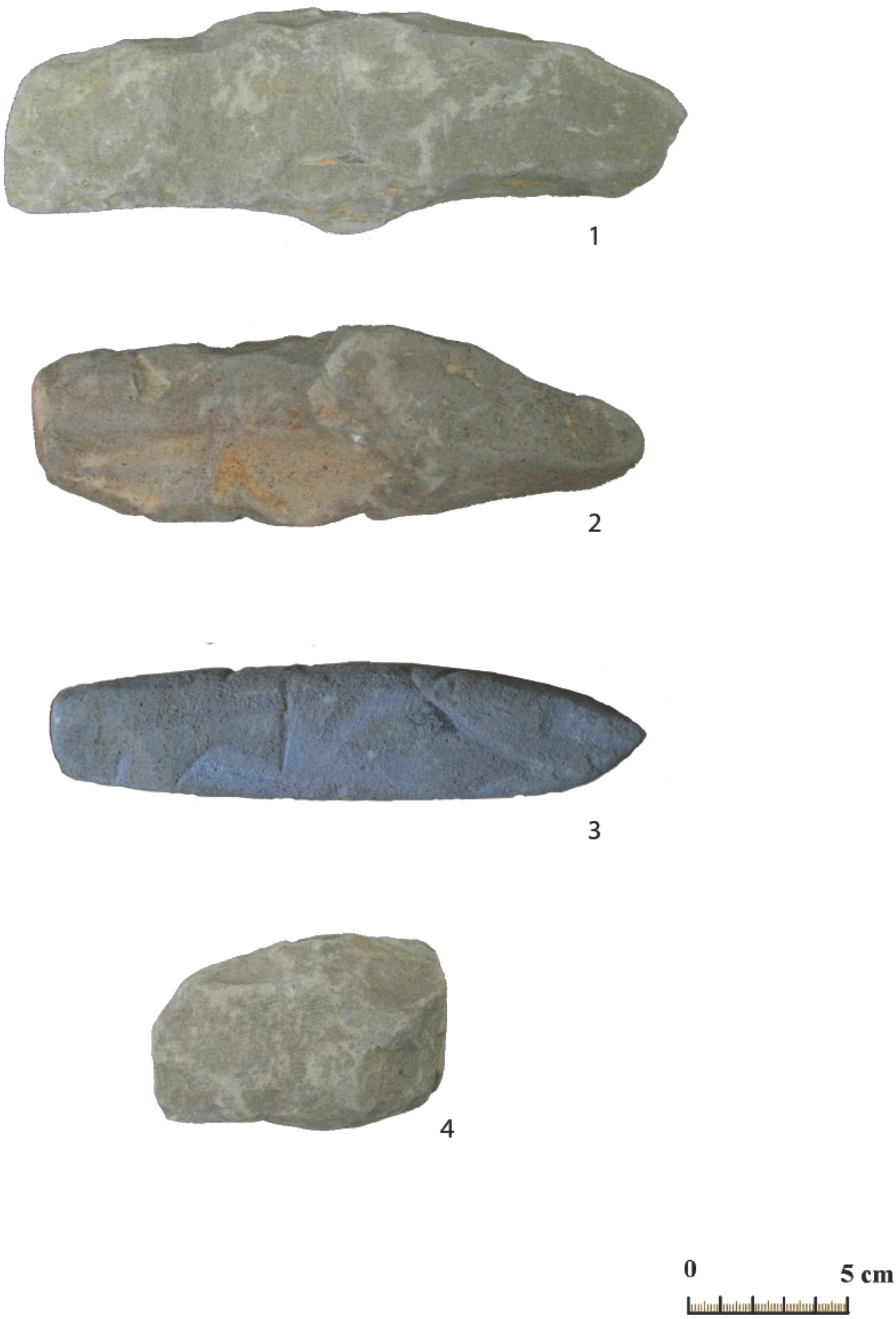

Fig. 5 – Half-products and preforms.

dimensions: l: 15.5 cm, w: 7.2 cm, h: 2.6 cm, weight: 533 g, another hatchet from Pénzesgyőr 66/W/1/6, Fig. 6:2, l: 12.3 cm, w: 6.2 cm, h: 2.6 cm, weight: 340 g as well as the hoe-blades 81/W/1/12 and 81/W/1/13 from Zirc-Királypatak (Fig. 6:3, dimensions: l: 11.8 cm, w: 4.4 cm, h: 2.6 cm, weight: 266 g and Fig. 6.4, dimensions: l: 13.7 cm, w: 4.7 cm, h: 3.6 cm, weight: 333 g, respectively. From the smaller blanks, carving tools, mainly chisels of triangular or trapezoid form were

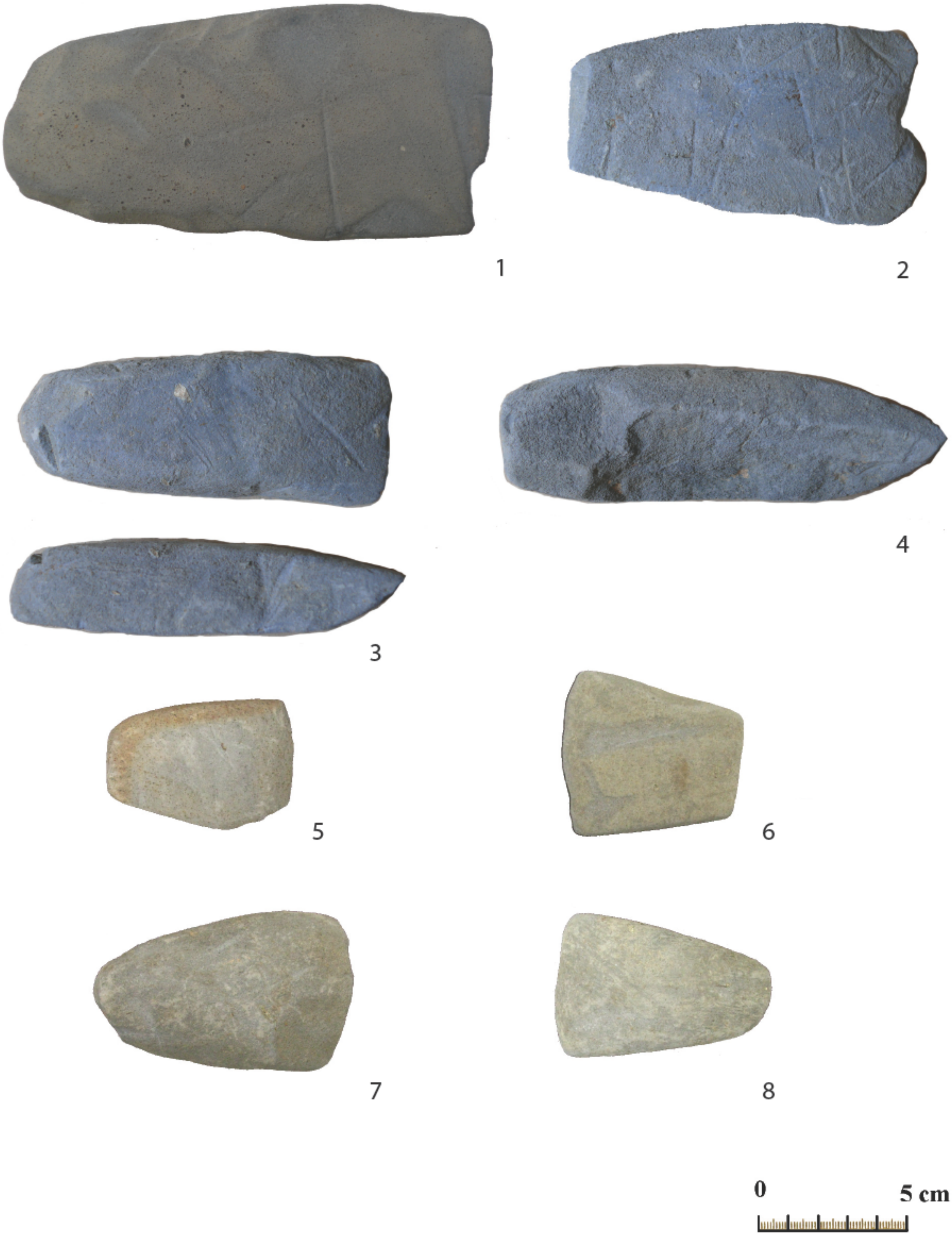

Fig. 6 – Finished polished stone tools made of basalt.

made with pointed or rounded butt, finished also with polishing. Characteristic examples include 66/W/1/88, 66/W/1/93, 66/W/1/96, 66/W/1/97, all of them from Pénzesgyőr.

66/W1/88, Fig. 6.5, dimensions: l: 6 cm, w: 4 cm, h: 1.6 cm, weight: 77 g.

66/W1/93, Fig. 6.6, dimensions: l: 6 cm, w: 5.4 cm, h: 1.2 cm, weight: 70 g.

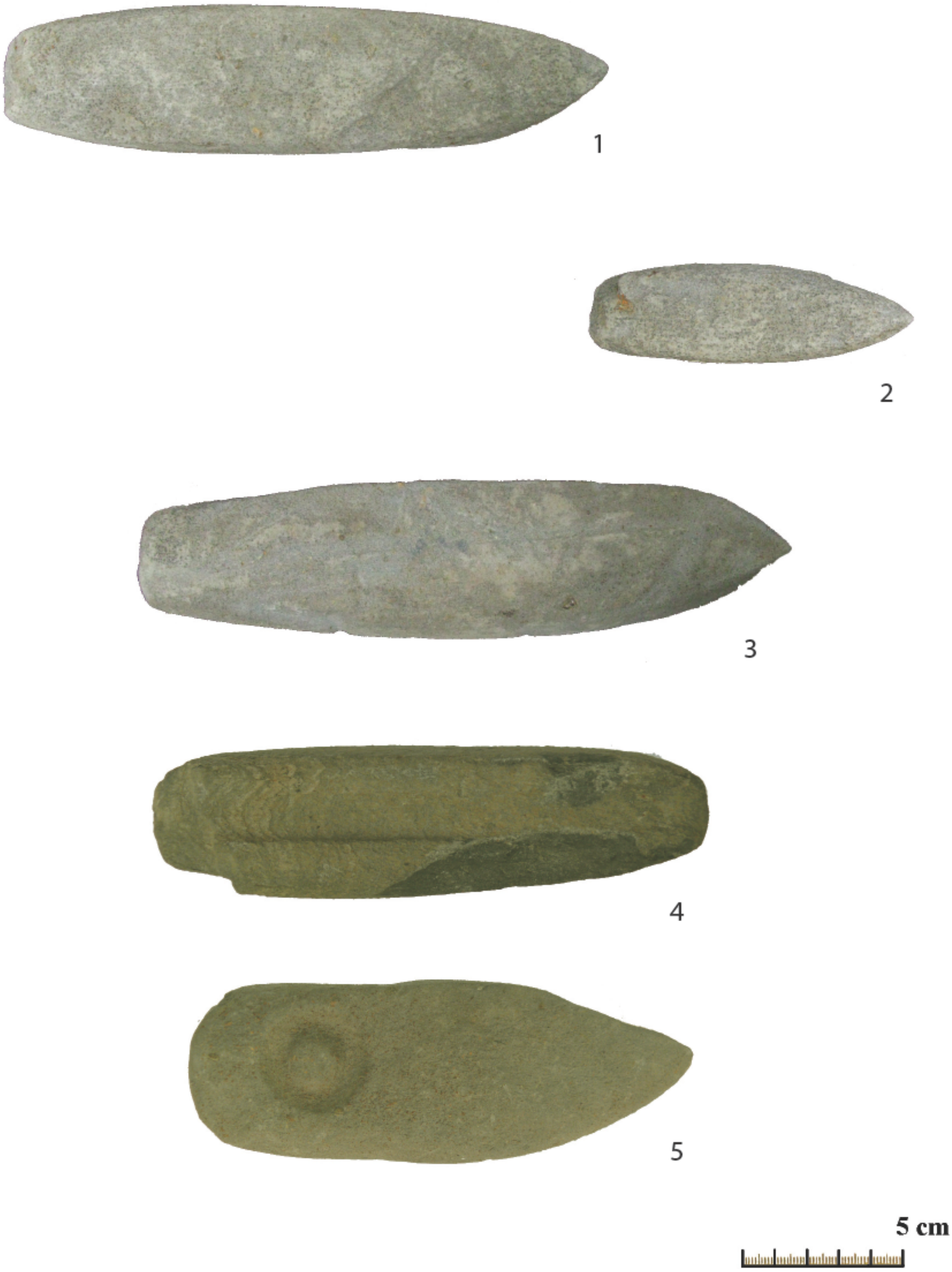

Fig. 7 – Polished stone tools made of basalt with punching technique (1, 2, 3); sawing (4) and preparation of drilling (5).

66/W1/96, Fig. 6.7, dimensions: l: 8.3 cm, w: 5.2 cm, h: 1.7 cm, weight: 128 g.
66/W1/97, Fig. 6.8, dimensions: l: 6.8 cm, w: 4.4 cm, h: 1.5 cm, weight: 80 g.

The blanks of proper shape were probably further shaped by chipping prior to polishing.

In the case of the larger (17-23 cm) shoe-last form tools, used as plane or chisel the processing is the same, the rough blanks were further formed by chipping before the final polish (e.g., Pénzesgyőr 66/W1/7, 66/W1/10, 66/W1/95). The corresponding dimensions were 66/W1/7, Fig. 7:1, l: 17.2 cm, w: 3.4 cm, h: 4.1 cm, weight: 458 g; 66/W1/10, Fig. 7:2, l: 18.2 cm, w: 3 cm, h: 4.1 cm, weight: 535 g; 66/W1/95, Fig. 7:3, l: 9 cm, w: 3 cm, h: 2.6 cm, weight: 130 g.

3.2.5. Form shaped by sawing

So far, only one piece was found in the Wolf Collection, the locality is Pénzesgyőr 66/W1/108, Fig. 7:4. It is 16.3 cm long, 3.6 cm wide and 4.1 cm high, the weight is 486 g. It is slightly narrowing towards the butt, probably used also as a percussion tool. The complete surface is covered by yellowish brown patina. On the sides we can observe fresh dark grey flakes of injuries. The rectangular percussion surface was made even by punching. On one side of the tool along the complete length of the piece we can find a 2.1 mm deep and 0.4 cm wide marked incision, with small injury towards the butt part. The incision clearly indicates the use of a saw-blade, probably made of wood and applied together with water and sand. We could observe a similar cut on the basalt plate of Veszprém-Kádárta (inv. nr. LDM 49.9780.583.1, ANTONI, 2012, fig. 5.) These cuts stand for the initial phase of the sawing. The Veszprém-Kádárta plate might have yielded similar pieces as the Pénzesgyőr tool.

3.2.6. Traces of drilling on finished tools, spoilt pieces and artefacts with secondary utilisation

In all probability, the shaft-hole objects were drilled using elder stems (*Sambucus nigra*) adding water and sand, starting typically from one side. The top and bottom diameter of the complete shaft-holes is nearly identical and they are relatively large (approx. 3 cm); for this, they needed an elder stem of similar, not much smaller size. These shaft-hole tools are fairly large (16-26 cm long) and relatively heavy used rather as weapons and prestige insignia than tools. They are not suitable for effective working, even as a hammer and we could not locate traces of use denoting potential utilisation on these pieces. On their surface we can sometimes locate traces of chipping e.g. on the adze-form tool from Zirc-Királypatak (81/W/1/2, Fig. 7:5, l: 12.7 cm, w: .7 cm, h: 4.3 cm, weight: 476 g). Seemingly the tool-maker was not very happy with the product but still tried to drill it through. The hole was started on the upper side of the implement with a stem of approx. 2.3 cm diameter and reached a depth of 0.5 cm; at that point, a conical inner plug core of 1.5 cm (below) and 0.8 cm (on top) was formed. At this point, the master finally gave it up and the piece remained unfinished or clearly spoiled.

Some characteristic forms are presented here, from Pénzesgyőr 66/W/1/1, Fig. 8:1, l: 24 cm, w: 120 cm, h: 70 cm, weight: 2924 g, 66/W/1/2, Fig. 8:2, l: 18.5 cm, w: 10 cm, h: 5.6 cm, weight: 1519 g, 66/W/1/4, Fig. 8:3, l: 15 cm, w: 9.2 cm, h: 2 cm, weight: 1321 g, 66/W/1/3 Fig. 8:4, l: 14 cm, w: 9.5 cm, h: 5.5 cm, weight: 1328 g, and from Zirc-Királypatak, 81/W/1/1, Fig. 9:1, l: 23.6 cm, w: -11 cm, h: 4.7 cm, weight: 1844 g. The tool 81/W/1/8 (Fig. 9:2, l: 21.5 cm, w: 10 cm, h: .4 cm, weight: 2083 g.) was broken to several pieces during the drilling. The diameter of the hole was 2.4 cm, started a bit obliquely, that is, spoilt from the beginning. The drilling penetrated into the rock for a depth of 0.8 cm. Another piece from Zirc-Királypatak (81/W/1/9, Fig. 9:3, l: 15.6 cm, w: 7.2 cm, h: 5.6 cm, weight: 1073 g is the product of the secondary use of a bigger piece with shaft-hole. On the current butt part, remains of a former complete drilled hole can be observed with 2.6 cm diameter. This specimen was also broken into three fragments; according to the patina, during the re-working.

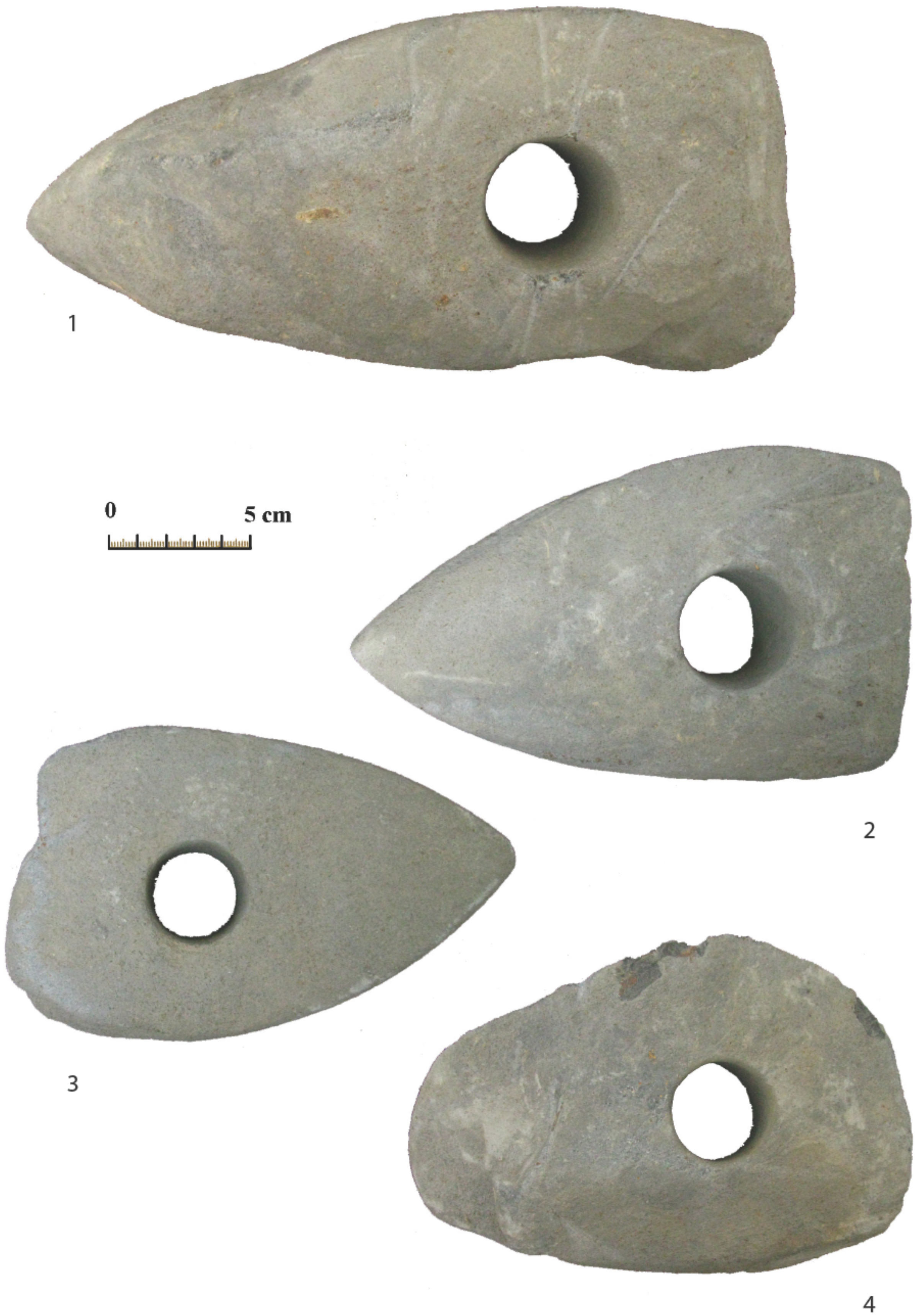

Fig. 8 – Polished stone tools made of basalt with drilled shaft-holes.

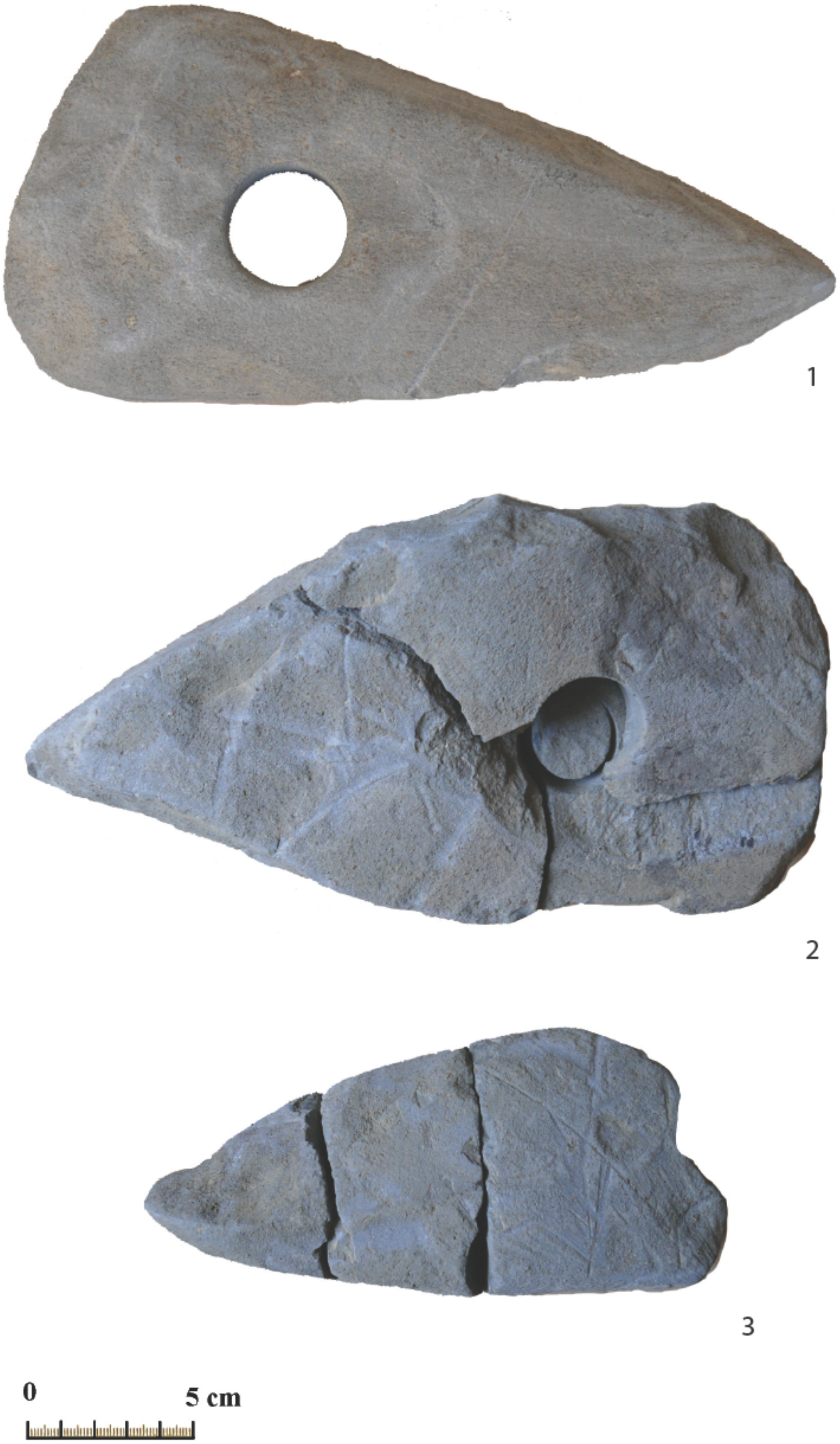

Fig. 9 – Polished stone tool made of basalt (1); spoilt and broken pieces (2, 3).

3.2.7. Tools for the production of the polished stone artefacts

The primary form of the tools produced were made first, selecting suitable blanks; then they were further worked by blows and chipping. Punching entered the process at a later stage. For this work, quartzite pebbles were used mainly, and the hard percussion tools show the characteristic traces of these activities. The two presented quartzite hammerstones are from Pénzesgyőr where they are probably local to the settlement. Both of them are basically oval and the traces of use can be observed on the lateral side in a stripe of 2-4 cm with characteristic small rough traces of the punching technique resembling to orange peel. In the course of work the hammerstone was held in hand by the thicker part. On this area the surface is intact or only slightly wrought.

The light coloured quartzite pebble (66/W1/109) is Fig. 10:1, l: 8 cm, w: 7.3 cm, h: 4.5 cm, weight: 401 g., the dark grey piece (66/W1/110) is Fig. 10:2, l: 8 cm, w: 7 cm, h: 4 cm, weight: 358 g.

The other important tool for the production of polished stone tools is the polisher proper, typically made of sandstone. The large polishers (50-100 cm) known from ethnographical evidence mainly, used for polishing large surfaces and setting the proper angle of sides was not found so far in Hungary. This can be explained, probably, secondary use for large boulders – for construction, millstones, etc. On the prehistoric sites we can come across the smaller, hand-held polishers, typically made of fine grained sandstone. They were used mainly for sharpening, honing the axeheads; when used up, they were easily discarded.

Fig. 10 – Tools for the production of the polished stone artefacts; hammerstones (1, 2) and polisher (3).

Such small hone stone is presented here from Porva-Ménesjárás (67/W/2/1) Fig. 10:3, l: 9.5 cm, w: 10.3 cm, h: 3.1 cm, weight: 284 g with a 7.3 cm long, 0.8-0.5 cm wide and 0.5 cm deep, slightly U shape depression for polishing edges. Apart from this long groove, a similar but shorter (ca. 3 cm long) and less deep (0.3 cm) depression is also visible that was in use probably prior to the long groove. The stone must have been a bit larger at the starting of the operation. The other side of the fine sandstone is flat and unused, the edges smoothed: This can be explained that from time to time, the piece had to be immersed into water.

4. Raw material for the basalt axes

The finished and used polished stone tools comprise several raw materials, notably basalt, greenschist, contact metabasite and serpentinite. They are typical for Transdanubian (especially Northern Transdanubian) Late Neolithic assemblages (FÜRI *et al.,* 2004; SZAKMÁNY, 2009).

Production debris, preforms and raw material blocks for polished stone axes were found exclusively of basalt raw material. Therefore we can suppose that the production of basalt tools took place on these sites whereas other raw materials (greenschist, contact metabasite and serpentinite) were probably brought to the site in finished artefact form.

The basalt raw material used belongs to the young (Plio-Pleistocene) basalts of the Balaton Highland and the Kisalföld (Little Hungarian Plain), respectively (FÜRI *et al.,* 2004). More exact location cannot be given for the time being. In course of the study of the Veszprém-Kádárta depot find (ANTONI, 2012), I. Oláh and co-authors tried to specify the source proper of the basalt preforms and raw material block (OLÁH *et al.,* 2012). They suggested as possible provenance the lava benches of Boncsos-tető (Hegyesd) and its vicinity, not excluding basalts of Hegyestű, Somló and Haláp either.

All these basalt outcrops are more, than a day's journey on foot from the archaeological sites mentioned in this paper; in fact, Veszprém-Kádárta is even further from the sources (Fig. 11, Fig. 12).

5. Conclusions

Important local production of basalt polished stone artefacts could be spotted on the Late Lengyel sites from Zirc environs. In spite of the character of acquisition (no systematic excavations; collection of field surveys alone), the scale of production is comparable to the known Hungarian polished stone tool production sites: Aszód (BIRÓ, 1992), Sé (BIRÓ, 1984), Zengővárkony (SCHLÉDER *et al.,* 2002; BIRÓ *et al.,* 2003). Preforms and raw material blocks are present on the sites comprising only

	Veszprém - Kádárta (Antoni 2012)	*Pénzesgyőr*	*Zirc*	*Porva*
Kabhegy	32	35	36	45
Sághegy	80	70	74	66
Somló	50	40	50	52
Hegyestű	41	48	56	60
Boncsos-tető (Hegyesd)	42	49	57	61
Haláp	50	55	65	67

Fig. 11 – Approximate distance of the most prominent basalt sources of the Balaton Highlands and the Hungarian Plain from the sites of the Wolf Collection (Zirc environs).

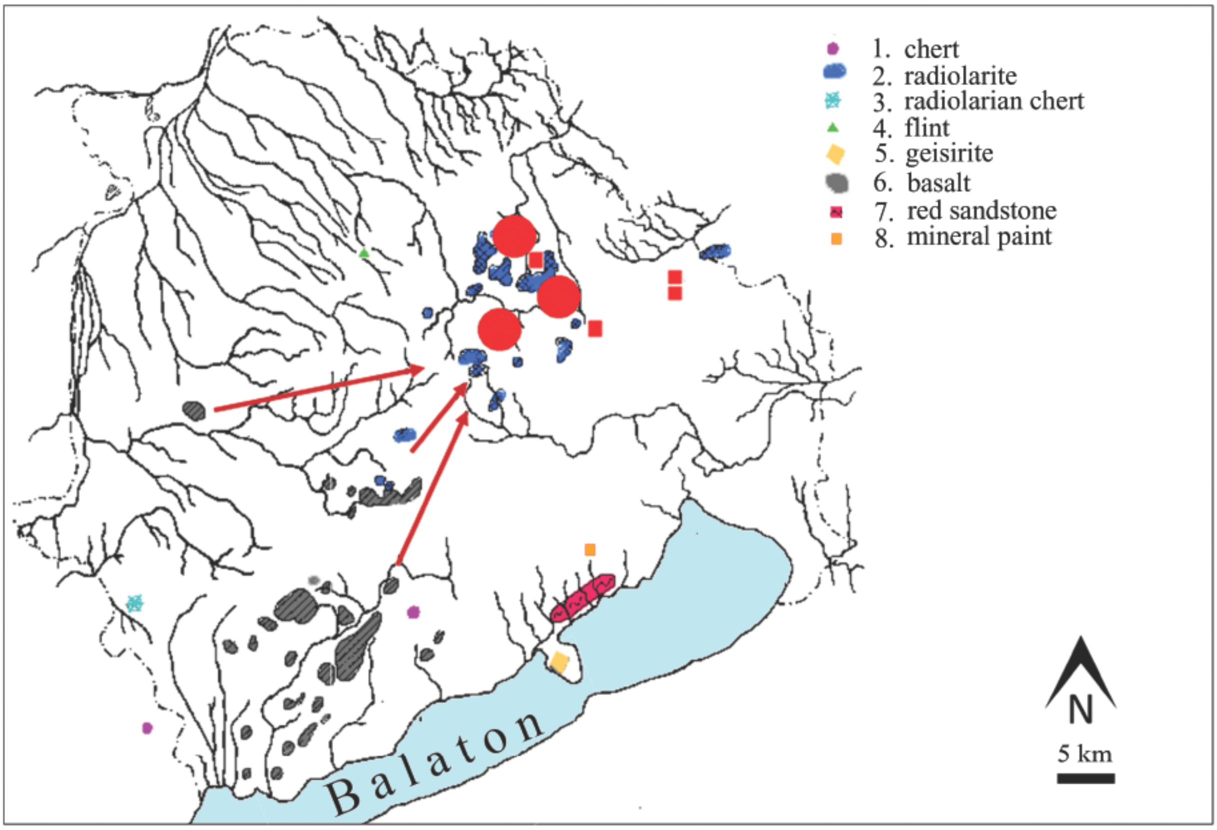

Fig. 12 – Possible provenance for the basalt artefacts in the Wolf Collection.

basalt. These preforms are so far the only known analogies to the depot find of Veszprém-Kádárta (also known as Gelemér or Litér junction). The actual basalt outcrops are in a distance of at least 40 km (or more typically 40-60 km) from the localities.

Other polished stone raw materials were imported to the site in ready-made form including exotic raw materials like greenschist, serpentinite, contact metabasite and even jadeite.

The sites presented here can be assigned to workshop districts II and III, respectively, in the terms of Biró & Regenye (2003).

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The photos were made by Krisztina Dúzs and the authors.

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Recent discoveries of human skeletons in the flint mine shafts of Spiennes: casualties or burials?

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Abstract

Since 1997, new archaeological research on the Neolithic mining area of Spiennes led to the discovery of two human skeletons in shaft ST11 and one in shaft ST6. Radiocarbon dating confirms their Neolithic age. This preliminary contribution shortly reviews the state of knowledge about human remains found at Spiennes, focusing particularly on recent discoveries.

Keywords: Flint mine, Neolithic, human remains, burial, relegation grave.

Résumé

Les recherches archéologiques menées depuis 1997 dans les zones minières de Spiennes ont conduit à la découverte de deux squelettes humains dans le puits ST11 et d'un squelette dans le puits ST6. Les datations au radiocarbone ont confirmé leur âge néolithique. Cette contribution préliminaire passe en revue brièvement l'état des connaissances sur les restes humains trouvés à Spiennes, en s'intéressant en particulier aux découvertes récentes.

***Mots-clés** : Minière à silex, Néolithique, restes humains, inhumation, sépulture de relégation.*

1. INTRODUCTION

Around 190 Neolithic flint mines have been recognised, from Scandinavia to Italy and from Belarus to Portugal as a pan-European phenomenon. Some of these mines have yielded isolated human bones and nearly complete skeletons, for instance Krumlovsky lès (Czech Republic), Vienna Mauer (Austria), Cissbury and Grime's Graves (UK) and Kleinkems (Germany).

In Belgium and neighbouring Dutch Limburg, three mining areas have yielded human remains, providing a major source of information about Neolithic societies.

a) The Maastricht area in the Netherlands and the adjacent Belgian Geer Valley. As Skull 1 unearthed in 1965 in the Neolithic Rijckholt-St. Geertruid mines, near Maastricht, has been discarded on the basis of a radiocarbon date (DE GROOTH *et al.*, 2011), the skull discovered by J. Hamal-Nandrin in the 'Schone Grub', a dry valley bisecting the Rijckholt mining area, is the only human remain which has been directly dated to the Neolithic period: 3840 ± 35 BP (GrA-26908; DE GROOTH *et al.*, 2011).

b) The central area, north of the city of Huy, where a burial was excavated in the village of Avennes, in 1945 (DESTEXHE-JAMOTTE, 1947). The discovery took place in a large mining site, in a pit which may be the top part of a mine shaft. The burial contained the bones of an adult man and two children, all in anatomical connection. A radiocarbon date by AMS was obtained using an adult cuneiform bone; OxA-6450: 4555 ± 60 BP, i.e. between 3500 and 3030 cal BC at 2 σ situating the individual between the very end of the Middle Neolithic and the beginning of the Late Neolithic (TOUSSAINT, 1998).

c) The region of Mons, where the mining area of Spiennes alone has produced relatively numerous human bones over the past 150 years; these findings are presented with more details in this paper. Thanks to radiocarbon dating, the so-called 'buried Neolithic flint miners' discovered in Strépy and Obourg are now rejected as a hoax (DE HEINZELIN *et al.*, 1993).

In Spiennes itself, contextual information about the discovered human remains is often very deficient. In fact, only the most recent excavations, undertaken since 1997 under the authority of the Public Service of Wallonia, provide satisfactory data in relation to the modern standards of archaeological and anthropological field research. For this reason, with the aim of improving the knowledge of the anthropology of the Neolithic populations of Spiennes as well as the methods of introduction of human bones into the mine shafts, an interdisciplinary research program was undertaken since 1997 under the authority of the Public Service of Wallonia. These new investigations relate mainly to the skeletons discovered in 1997 in shaft ST11 but also to the skeleton being currently excavated in shaft ST6. F. Hubert's discoveries in 1965 and the SRPH's discoveries in 1979, which had not really been studied so far, are also briefly presented, while earlier discoveries, discussed in various articles (among others COLMAN, 1957; DE HEINZELIN *et al.*, 1993), are simply summarised.

Research is being developed in three areas: firstly, archaeothanatology which aims to decode the nature of bone deposits (deliberate

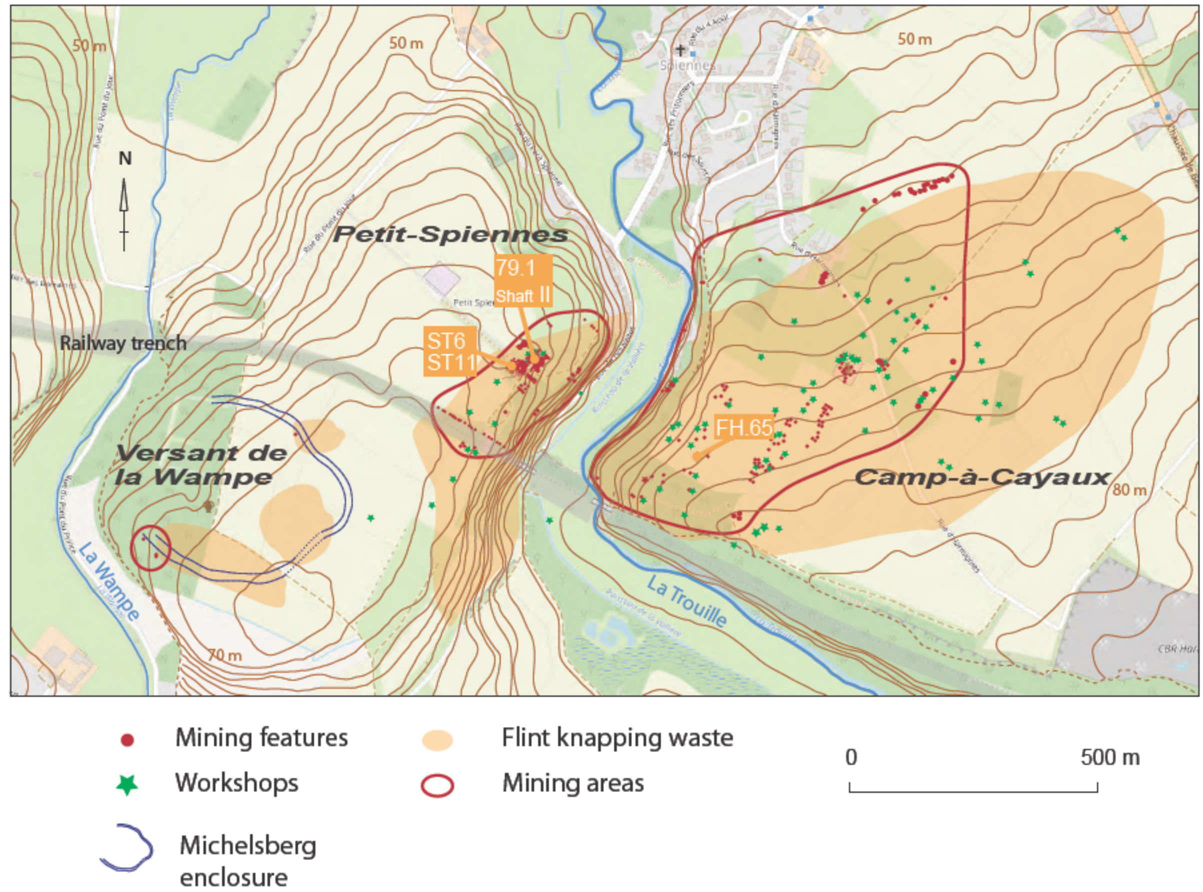


Fig. 1 – Map of the three mining areas of the Neolithic flint mines of Spiennes with location of the human remains from recent shaft excavations. FH65: excavation by F. Hubert in 1965, shaft II & 79.1: excavation by the Society for Prehistoric Research in Hainaut from 1953 to 2010, ST6 & ST11: excavation by the Walloon Heritage Agency from 1997 to 2004 and from 2013 to 2019. Background map: OpenStreetMap, licence Open Data Commons Open Database.

character of the deposits or not, cause of death, type of funerary deposits, primary or secondary burials...); secondly, 'classical' anthropological studies (number of subjects, age, sex, stature, activity markers, pathology...); thirdly, biological and geochemical analysis (14C, isotopic determination of C and N or strontium, palaeogenetics...).

2. The mining area of Spiennes

The mining area of Spiennes (COLLET, 2016) is located approximately 5 km south-east of the city of Mons (Province of Hainaut, Belgium). It comprises of three Neolithic mining areas (Fig. 1). They are called 'Camp-à-Cayaux', 'Petit-Spiennes' and 'Versant de la Wampe'. The Interpretation Centre of 'Petit-Spiennes' is situated 50° 25' 12.032" N, 3° 58' 56.971" E by the geographical coordinate system, while the Archaeological Research Centre of 'Camp-à-Cayaux' is 50° 25' 11.013" N, 3° 59' 29.137" E. It was estimated that as many as 15 to 20,000 shafts could have been dug covering an area of around 50 to 100 ha, exploited in the three zones of Spiennes, from approximately 4350 cal BC to at least 2800 cal BC, and possibly to 2300/2200 cal BC.

'Camp-à-Cayaux' and 'Petit-Spiennes' have yielded human remains, exhumed from the mid-19th century to the last few years. These are isolated bones or skeletons of varying completeness.

In addition to the 14C dates obtained from fauna, charcoal and antler tools (COLLET *et al.*, 2008b), 17 radiocarbon dates were obtained from these human bones (Fig. 2), of which 12, were presented in a first article (TOUSSAINT *et al.*, 2010). Of these 17 dates, 16 correspond to the Neolithic period, while the last one confirms the long-suspected attribution to the Merovingian of the skeletons found in 1919 in the slope of the 'Camp-à-Cayaux' (RUTOT, 1920; DE HEINZELIN *et al.*, 1993). Precisely, all the Neolithic dates obtained on human bones range between 5160 ± 45 BP (OxA-8874) and 3775 ± 40 BP (GrA-50661), or in calibrated dates at 2 σ between 4049 and 3803 cal BC and between 2338 and 2030 cal BC (Fig. 2). They overlap with the 24 dates obtained on other material from the mines and related sites (COLLET *et al.*, 2008b; COLLET, 2016) and confirm that the mines of Spiennes have been active in both the Middle Neolithic and the Late and Final Neolithic.

The Spiennes mining complex also included a ditched enclosure in the 'Versant de la Wampe' mining area, composed of two concentric ditches and banks. No human bone has been reported so far in this area. The associated archaeological material found in the enclosure can be attributed to the Michelsberg culture (HUBERT, 1971) and, more specifically, to the 'Central Scheldt basin group' (VANMONTFORT, 2004, p. 342), connected with the Michelsberg culture groups from the Paris Basin, the Middle Meuse and the Rhine Basin. As the potteries of the enclosure do not show real difference with those found in the mining areas, and according to some 14C dates, the settlement looks contemporaneous with at least part of the mining activity at Spiennes (COLLET *et al.*, 2008a).

3. Human bones found from at least 1867 to around 1960

Some human bones belonging to the partial skeleton of a child from 3 to 6 years were identified as early as 1867 in one of the mining shafts probably found in the trench dug during the construction of a railway, near 'Petit-Spiennes' ('Spiennes C'; DE HEINZELIN *et al.*, 1993). Other human remains could even have been found earlier (HUBERT, 1988, p. 15) or possibly just before 1875, such as the cranial fragments and long bones known as 'Spiennes Y' belonging to at least two individuals, but from uncertain provenance (DE HEINZELIN *et al.*, 1993).

During the last decades of the 19th century and the first of the 20th century, extensive mining excavations were carried out and several human remains were discovered but without accurate stratigraphical and archaeological contexts. They can be divided into two series:

a) More or less isolated skulls.
   On several occasions, more or less isolated skulls, cranial fragments and mandibles were

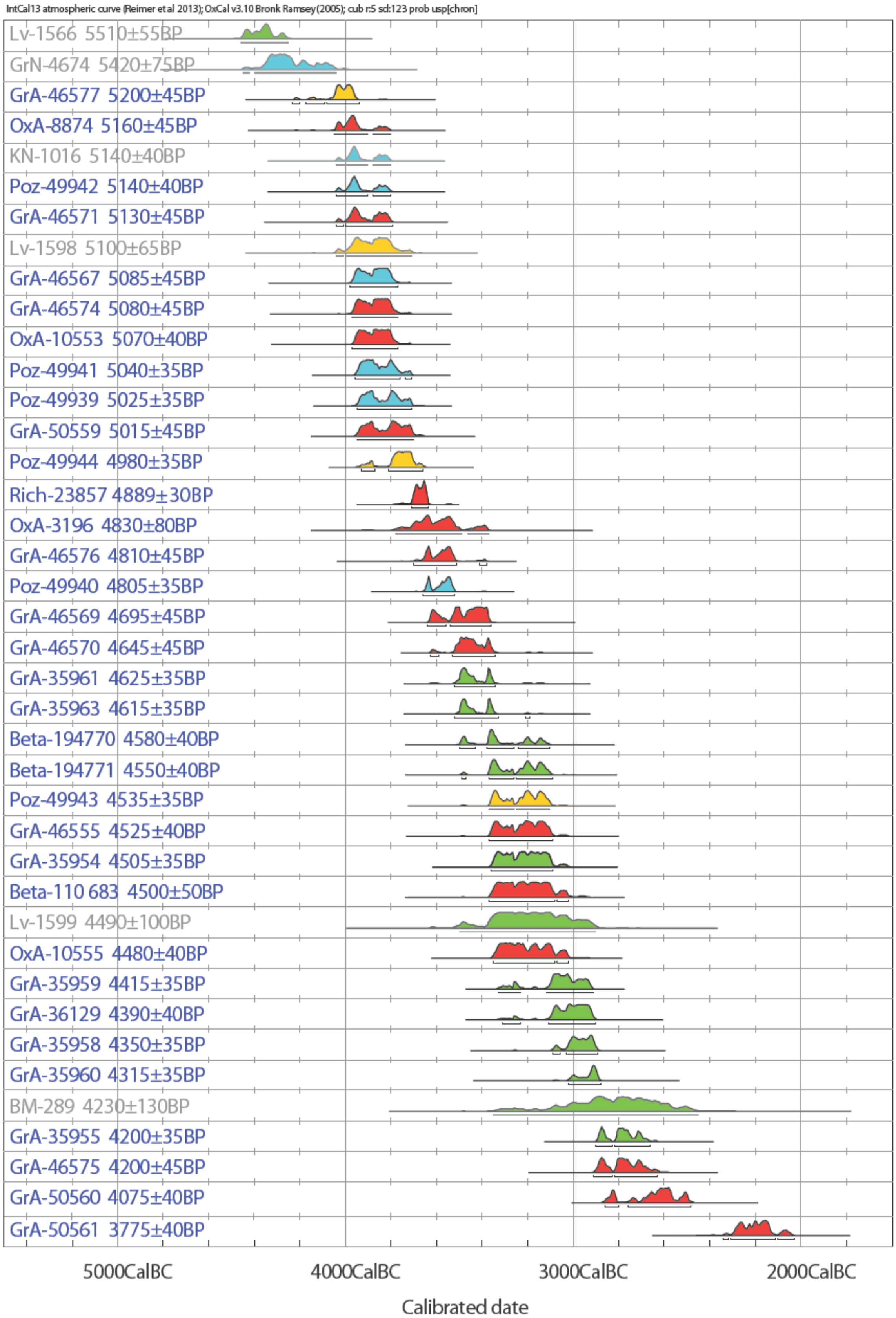


Fig. 2 – Radiocarbon dates of the Neolithic flint mines of Spiennes. Dates obtained on human bones are in red, animal bones in yellow, charcoal in blue, antlers in green. Date references in light grey outline correspond to conventional dates and dark blue outline to AMS dates.

exhumed in the upper part of mine shafts at Spiennes. Their findings are not very precise. Four of these discoveries have led to numerous discussions. During excavations of features 3 ('Spiennes I & J' of DE HEINZELIN *et al.*, 1993) and 5 ('Spiennes L') at 'Camp-à-Cayaux', A. de Loë and E. Rahir (1929, p. 55) discovered three skulls without mandibles and interpreted them as 'secondary burials' with grave goods. Following the discovery in 1953 of a new skull without mandible, J. Verheyleweghen (1962) again vigorously defended this idea. Such an interpretation has been strongly contested, notably by P. Colman (1957) and J. de Heinzelin *et al.* (1993) and is now completely rejected, based on many arguments. The relationship between the isolated skulls and what is considered as grave goods is far from established. Secondly, these artefacts offer nothing particular which would guarantee its funerary character itself. Thirdly the shafts in which skulls were interpreted as second degree deposits were only partially excavated. It is therefore possible that the rest of the skeletons still lay in the shafts. Fourthly, the stratigraphy with almost horizontal layers proposed by the former excavators is

Fig. 3 – Spiennes 'Camp-à-Cayaux': sketch of the arrangement of skeletons D & E exhumed in 1911 by the digger C. Stevens on behalf of the Natural History Museum (now Royal Belgian Institute of Natural Sciences).

clearly fanciful in view of those observed in more recently excavated features which eliminates any form of a serious guarantee regarding the context of these skulls. Fifthly, while the isolated skulls are interpreted as secondary burials, the isolated postcranial bones are not, which is inconsistent.

b) Partial or fairly complete skeletons.

In January 1911, C. Stevens unearthed a relatively complete adult skeleton and a child of about twelve years in a pit with vertical walls, possibly the upper part of a mine shaft. Only a brief sketch has been produced (Fig. 3). It shows the adult ('Spiennes D') lying at 1.43 m deep, on its back, legs down. The skeleton of the child ('Spiennes E') was extended with head at the opposite side of the pit, slightly oblique to the axis of the adult body. The inaccuracy of the sketch makes it impossible to determine whether there was a real interconnection between the two skeletons. Curiously, however, the radiocarbon dates of the two Neolithic skeletons differ from 300 years BP and their calibrations, both at 1 and 2 σ, do not overlap. These two skeletons could correspond to burials largely more or less *in situ* (probable anatomical connections...). A triangular arrowhead has been found under the adult skeleton, which could either play in favour of funerary material or be linked to an injury.

4. HUMAN REMAINS OF THE 1965 EXCAVATION BY F. HUBERT (FH65)

A small series of 82 human bones, often reduced to fragments, was discovered at 'Camp-à-Cayaux' in the upper part of the shaft no 3/ workshop no III during the 1965 field campaign of the *Service national des Fouilles*, at depths ranging from ± 125 cm to ± 165 cm (Fig. 4). These fragments were not identified as human during the excavation. They are preserved in the store rooms of the Walloon Heritage Agency of the Public

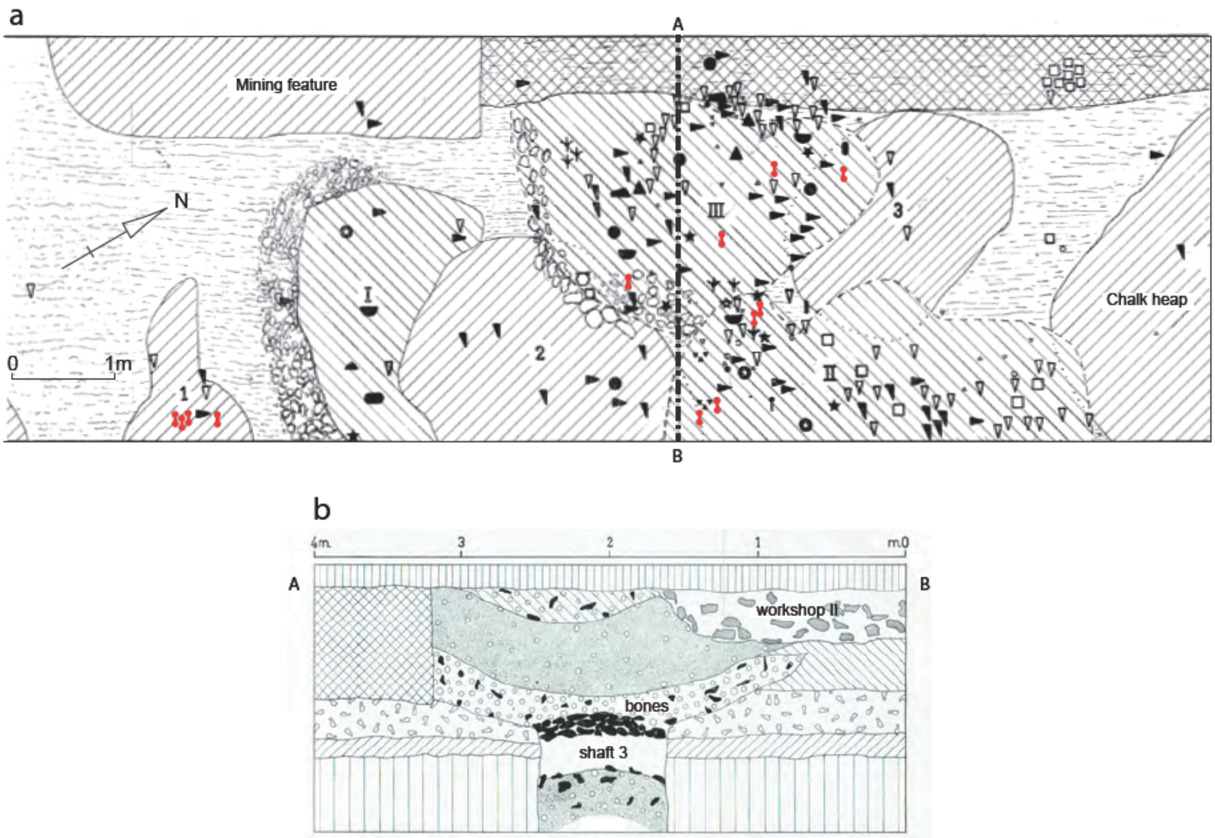


Fig. 4 – Excavation of the summit part of the shaft 3 and workshop III at Spiennes 'Camp-à-Cayaux', by F. Hubert, a: plan; b: section. Red symbols: bones; the other symbols correspond to the different types of material (flint, sandstone fragments and deer antlers), after HUBERT, 1969, p. 22.

Service of Wallonia, mixed with six animal bones, in two boxes with labels written by F. Hubert, the excavator (HUBERT, 1969).

After refitting the 82 fragments, the collection contains only 22 identifiable bones, but all of them are incomplete with respect to their original anatomical state, as well as ten unidentifiable fragments. The intensity of fragmentation is therefore maximal. These 22 elements represent only 10.7 % of the 206 bones of an adult skeleton (BASS, 1971). Given the young age of the subject, in which all three parts of the long bones have not yet been welded together, this proportion is even smaller.

The skull and pelvis are not represented in the collection. The shoulder girdle is attested by the left clavicle and the left scapula, the arm by the two humerus, the forearm by the right radius and the right ulna. The two lower limbs are represented, on the right by the tibia and fibula, on the left by the femur and fibula. The ossicles of the hands and the feet are not preserved. Fourteen elements come from the left side of the body, five from the right side and three indeterminate.

All these remains come from a single juvenile individual. In the absence of teeth, it is difficult to estimate its age. He or she was approximately ten years old, given the dimensions of the long bones in comparison with sets of bones of known age. Trying to determine the sex of an immature skeleton by strictly anthropological methods is almost impossible, especially in the absence of the pelvis; this has not been attempted here.

No excavation plans and photographs of the *in situ* human bones have been made. It is therefore not possible to verify the presence or absence of anatomical connections and the spatial proximity of bones belonging to the same areas of the body thus making it impossible to determine whether or not the human bones found in 1965 correspond to a burial site.

A human rib was used to obtain a radiocarbon date by AMS: 5080 ± 45 BP (GrA-46574), i.e. 3953-3804 cal BC after calibration at 2 σ and 3971-3775 at 1 σ.

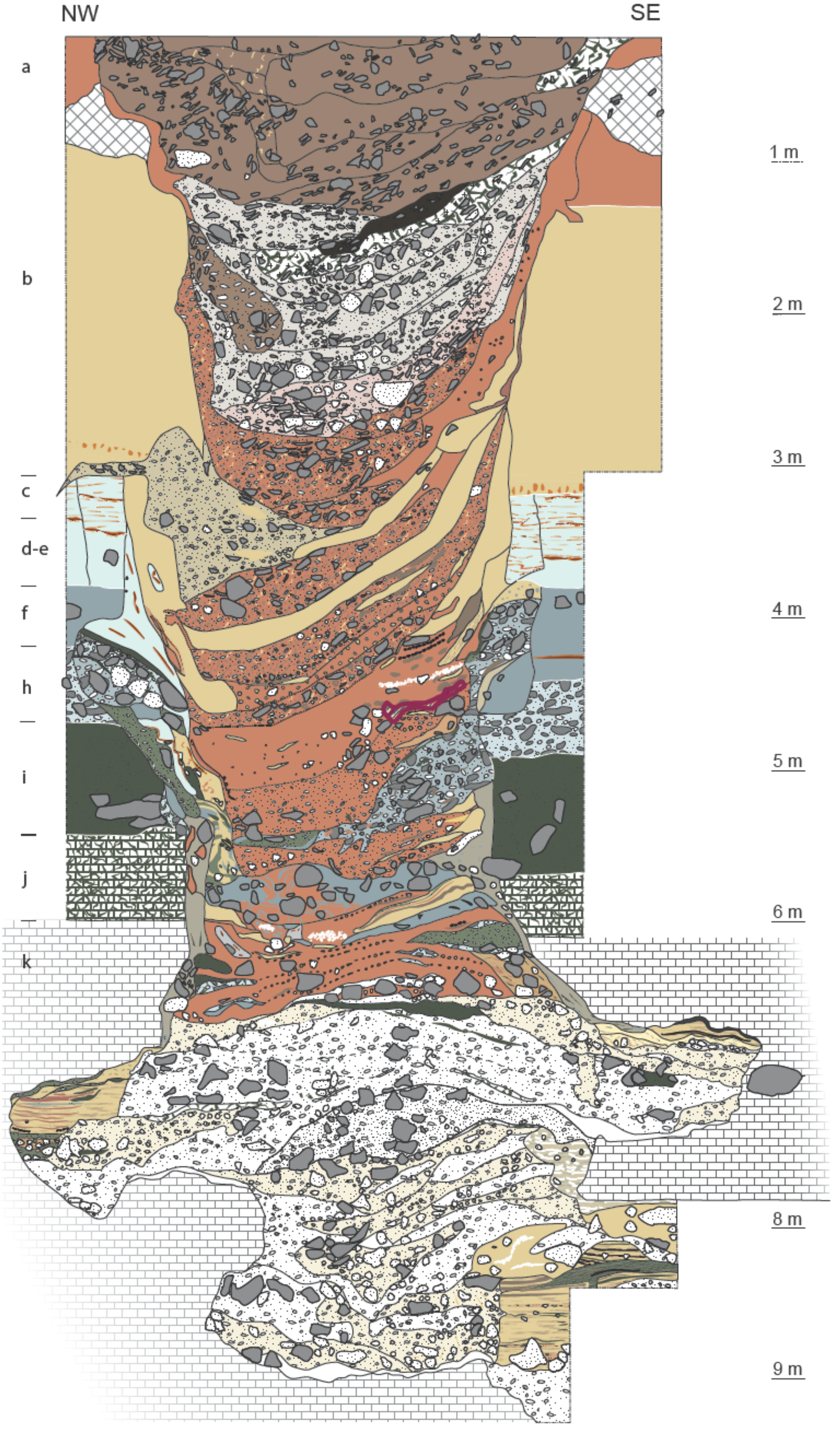
5. EXCAVATIONS OF THE SRPH (79.1)

A few human remains were discovered in a deposit interpreted as a mudflow (*coulée boueuse*) overlying the chalky mining waste at the base of shaft 79.1 of the SRPH (Society for Prehistoric Research in Hainaut) excavation at 'Petit-Spiennes' (GOSSELIN, 1986, p. 148). In the SRPH collections, only two documents are currently present (in 2017), the posterior half of an adult left calcaneus and an intact fourth left metatarsal. Only the base of the latter is still preserved, the body and head of the bone being used to obtain the AMS OxA-8874 date at 5160 ± 45 BP, or at 2 σ between 4050 and 3800 cal BC (COLLET *et al.*, 2011). Contra Gautier (in GOSSELIN, 1986, p. 148), it is not possible to be sure of the number of individuals represented by the two bones. They may very well have belonged to one individual as well as to two different individuals. Both bones are clearly adult and, at least for the metatarsal, could have belonged to a male because of its dimensions well above the female average and close to the male average of Mountrakis *et al.* (2010). There is no serious element to determine the cause of the introduction of the bones into the shaft.

At least two human remains belonging to the upper limb were also excavated in shaft II of the SRPH excavations. These are an ulna and a radius that have not been presented to us for study. Colman (1957, p. 252) mentions the additional discovery of a femur and a tibia: either these two bones have been lost or are hidden in museum collections, or there have been erroneous anatomical determinations in the field of the two previous bones.

6. RECENT DISCOVERIES: 1997 ONWARDS

The excavations conducted recently at 'Petit-Spiennes' by H. Collet and the Public Service of Wallonia involved three mine shafts which were excavated almost exhaustively to the bottom: ST6 (1999-2004 and 2014-ongoing), ST11 (1997-1999) and ST20 (1999-2004 and 2013). The first two have each delivered a nearly complete adult skeleton, accompanied by a newborn in the case of ST11.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6.1. Survey methods

Accurate and detailed recording of the archaeological context is essential to have the slightest chance of decoding, at least in part, the phenomena responsible for the arrival of the human bones in mine shafts.

To this end, the digging of the ST11 adult skeleton in 1997 was carried out in collaboration between the archaeological team in charge of the site and the anthropologist. A natural-sized drawing of the skeleton has been done. Several photographic records were also made. All bones, even the smallest fragments, have been accurately identified *in situ*. Details of their morphology (epiphyses, faces, processes and furrows, ridges, crests ...), their lateralisation, the state of the connections (both labile and persistent), the displacements, the morphology of the breaks and the state of conservation of each bone have been precisely recorded.

The excavation of the ST6 skeleton in 2014-2019 applied the same principles, but with two notable improvements. In addition to the systematic presence of the anthropologist at each stage of the bone survey, the excavation involved a geologist who focused on deciphering the numerous layers of the feature and interpreting the various sedimentary processes. The ultimate goal is to better understand the detailed history of the filling of the shaft, including the history of the introduction of human bones, taking into account the data from all the involved disciplines. Secondly, instead of making a plan on paper, digital photographs of each bone were transferred to a tablet on which the anthropologist and geologist recorded details of their anatomical and stratigraphic observations, while the archaeological team specifically used the total station in order to reconstruct a general plan and 3D views during the post-digging process.

6.2. The skeletons of shaft ST11 and their context

Two human skeletons were discovered in the ST11 shaft: an almost complete adult (TOUSSAINT *et al.*, 1997; COLLET & TOUSSAINT, 1998) and some fragments of a newborn (COLLET & VAN NEER, 2002). A 14C date by AMS was performed using the left cuboid of the adult skeleton; Beta-110683: 4500 ± 50 BP, i.e. between 3338 and 3103 cal BC after calibration at 1 σ and between 3362 and 3027 cal BC at 2 σ. The perinatal skeleton was also subjected to an AMS dating made from a right humerus: GrA-46555: 4525 ± 40 BP, i.e. between 3353 and 3114 cal BC after calibration at 1 σ and between 3363 and 3097 cal BC at 2 σ.

On the basis of the degree of closure of the seven sites of the vault of R. Meindl and C. Lovejoy (1985), the adult, possibly a male, corresponds to an average age at death of 45.2 ± 12.6 years. Examination of the right sacroiliac surface by the method of A. Schmitt (2005) gives a higher age that has 90 % chance of matching a subject over 60 years of age at death. Regardless of the estimation method, the deceased of the ST11 was therefore an elderly adult.

Most of the adult bones were arranged in an inclined plane at about 40° on an elongated surface of about 2 m in length, 40 to 60 cm in width and hardly more than 30 cm thick, at depths ranging from ~4 m to ~5.5 m (Fig. 5, Fig. 6). The thickness of the bone cluster was visibly lower than that of a body not yet decomposed. Decomposition obviously occurred in the shaft, as evidenced by the presence of numerous bones from all parts of the skeleton and their anatomical position.

The position of the skeleton was clearly recognisable with the lower limbs located at the top to the south-southwest of the deposit and the

Fig. 5 – (opposite page) Petit-Spiennes, mining shaft ST11. Section with position of some of the human bones discovered (purple hatched area) and stratigraphic context; a: clayey silt (Bt horizon); b: loess; c: silt and silty sand; d-e: light grey sandy silt; f: greenish grey clayey/sandy silt; h: flint blocks and chalk nodules in grey to greenish grey sandy matrix; i: dark green sandy matrix; j: *in situ* weathered chalk; k: *in situ* chalk.

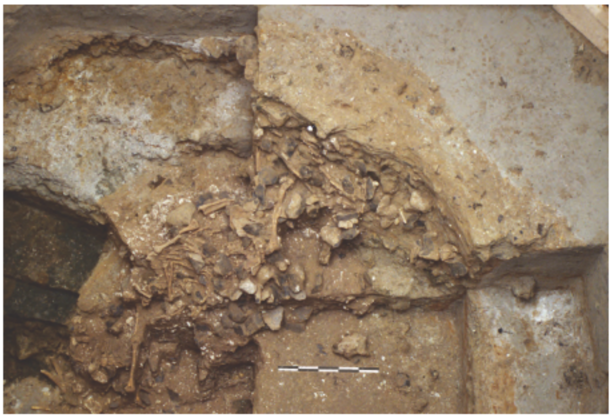


Fig. 6 – 'Petit-Spiennes', mining shaft ST11. The adult skeleton being excavated.

head at the base to the north-northeast. However, many positional anomalies were present due to displacements of bones and sediments. In fact, it is possible to distinguish three areas in the distribution of bones:

- In the upper part of the bone deposit, the distal zone of the lower limbs (fibulas, tibias, patellas and bones of the feet) largely dislocated but some bones are matched;
- In the intermediate area of the bone deposit, the part of the skeleton that best respects the anatomical distribution of a skeleton, appearing in some sectors in more or less strict connection and crushed in place. This area includes the femurs, the coxal bones, the left part of the rib cage, the left scapula as well as the lumbar vertebrae and part of the thoracic vertebrae.
- In the lower part of the bone deposit, the right part of the chest and the area of the head and right arm; these bones are disconnected but still have some anatomical proximity.

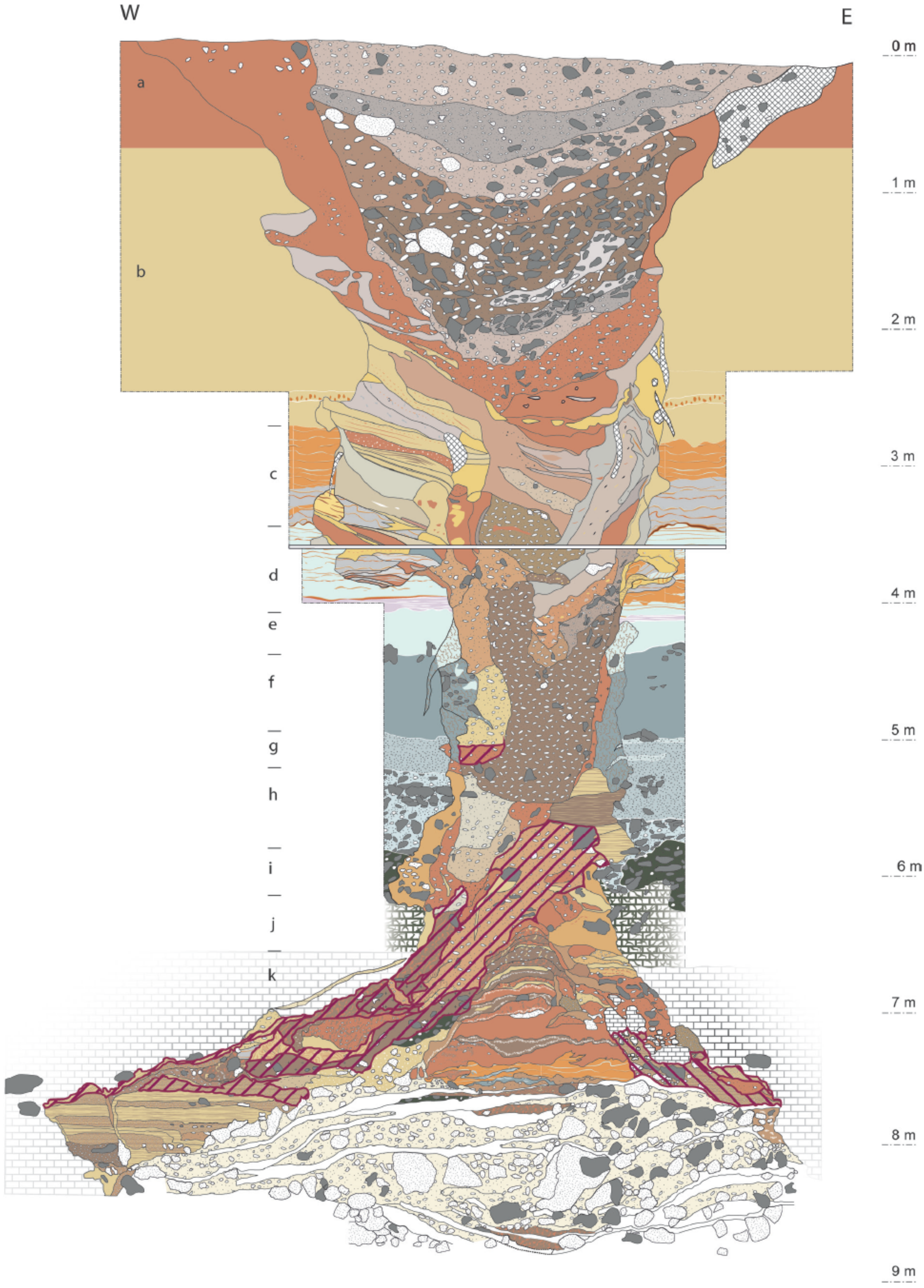
The bones of the new born were discovered in a small area between 4.8 and 5.2 m in depth, well apart from the adult skeleton, while a single bone moved down up to about 6.2-6.4 m in depth. Unfortunately the human bones of the perinatal were not recognised *in situ*, preventing a study of its disposition.

6.3. The skeleton of shaft ST6 and its context

From the summer of 2014 until the end of 2019, human bones were unearthed at the bottom of the ST6 shaft and in the upper part of the filling of the galleries. The anthropological excavation, which will be continued in 2020, is conducted by the Public Service of Wallonia in collaboration with the SRPH (LAVACHERY *et al.*, 2015; COLLET *et al.*, 2016).

All bones discovered so far belong to a single adult individual, probably a man. Because many cranial fragments are still missing, it is not possible to estimate the degree of closure of many diagnostic anatomical sites used by R. Meindl and C. Lovejoy (1985). At most, it can be noted that the degree of closure of the sutures of ST6 individual is less than in ST11, which would argue in favour of a slightly younger subject. Examination of the two sacroiliac surfaces by the method of A. Schmitt (2005) gives a subject who has 99 % chance of being over 50 years old at death.

Fig. 7 – (opposite page) 'Petit-Spiennes', mining shaft ST6. Section with position of layers including human bones (purple hatched area) and stratigraphic context; a: clayey silt (Bt horizon); b: loess; c: cryoturbated unit composed of silt and silty sand passing to pure sand at the bottom (the sand part corresponds to SG unit of Di Modica *et al.*, 2014); d: alternating thin layers of sandy silt and clayey silt from light grey to light pink in colour (SLAS unit); e: light grey sandy silt (LHGC unit); f: greenish grey clayey/sandy silt (LGV unit); g: beige-yellow coarse and medium coarse cross-bedded sands (SGC unit); h: flint blocks and chalk nodules in grey to greenish grey sandy matrix (K unit); i: flint blocks and chalk nodules in a dark green sandy matrix; j: *in situ* weathered chalk; k: *in situ* chalk. For more details about units K to SG, see DI MODICA *et al.*, 2014.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At the present state of excavation, the human bones have been found from depths 5.5 to 7.9 m (Fig. 7, Fig. 8). These remains have been unearthed from several distinct stratigraphic units. Taking into account the spatial and stratigraphic distribution of the remains, as well as the study of the sedimentary processes (including dry grain flow, run-off, and debris flow), it is clear that the human body underwent a complex history, including several phases of redistribution. Given the available data, our best hypothesis is that the body was introduced in the shaft (accidentally or deliberately) and that complex post-sedimentary processes affecting the shaft filling lead to a

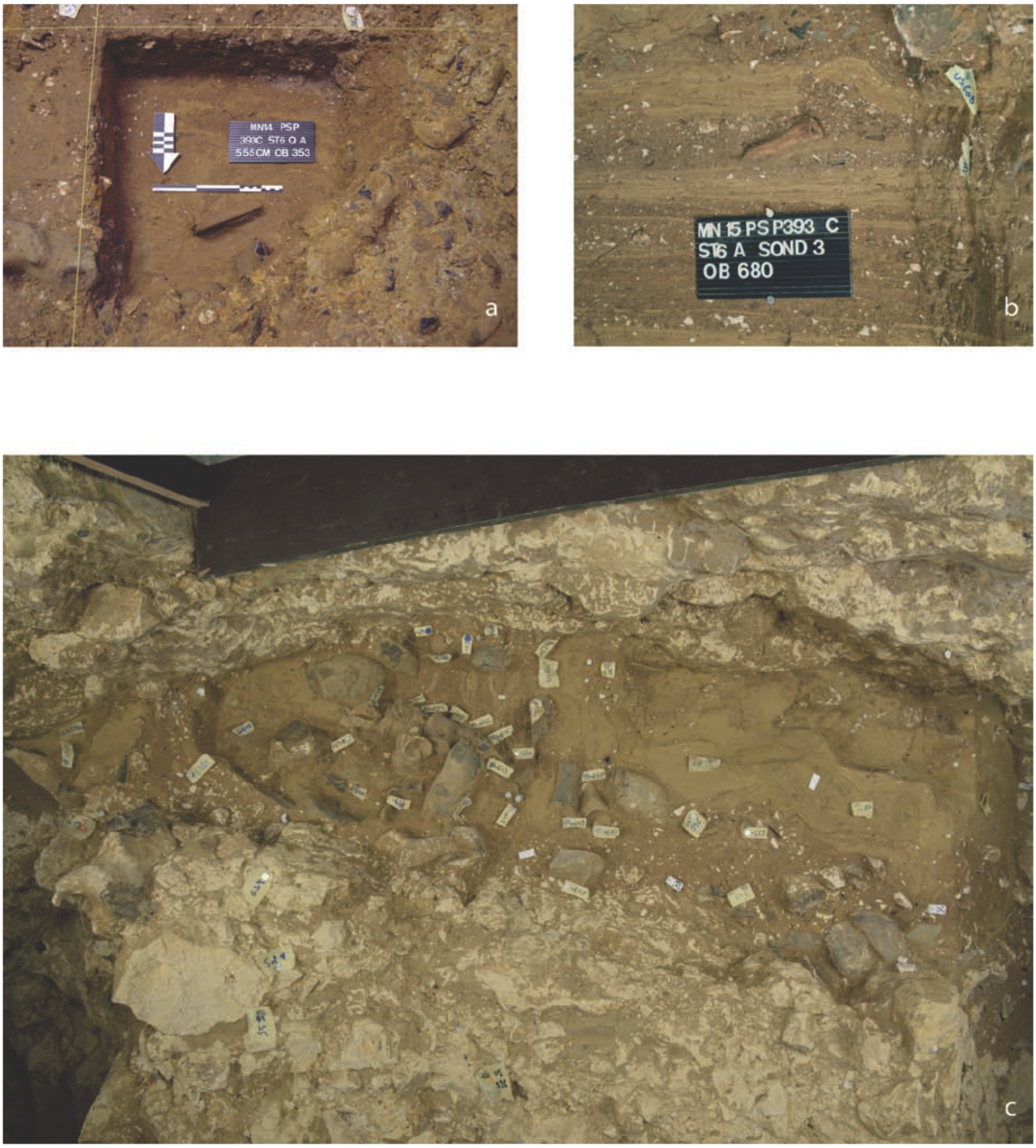

Fig. 8 – 'Petit-Spiennes', mining shaft ST6. Human bones in various stratigraphic contexts; a: tibia fragment found at 5.5 m deep (item no 353), b: tibia fragment found at 7.65 m deep (item no 680), c: sacrum articulated to lumbar vertebrae found between 7 and 7.2 m deep (items no 622 and 638-642).

multi-phased reworking of the corpse. In the near future, a combination of the available stratigraphic records, the anthropological data, and the exact spatial position of all the human remains should allow determining with more details the succession of events, and should help better deciphering the mode of introduction of the human body in the ST6 feature.

All the anatomical areas of the skeleton are present: skull, shoulder girdle, trunk (ribs and vertebrae), upper limbs and hands as well as to lower limbs and feet. Most of these are disconnected. However the sacrum and the two coxal bones were still in connection, a little open, and the sacrum articulated to the lumbar vertebrae.

6.4. Musculoskeletal Stress Markers (MSM)

The study of the morphology and development of areas of muscle attachment to bone, often referred to as musculoskeletal stress markers, or MSM, is frequently used to determine occupational patterns and sociocultural divisions of activity in populations (i.e. CAPASSO *et al.*, 1999; MARIOTTI *et al.*, 2007; VILLOTTE, 2009). In fact, when a muscle is heavily used, its insertions on the bones are supposed to become stronger. However, some studies suggest that MSMs are also age structured within human groups (TAKIGAWA, 2014).

The bones of ST6 and ST11 show various well-developed insertions. For example, the humerus of ST6 presents a strong deltoid tuberosity. So, the deltoid muscle was powerful and well adapted to hard work. This muscle originates in three distinct sets of fibres which arise from the clavicle and scapula, forming the rounded contour of the shoulder, then converging toward their insertion on the deltoid tuberosity on the middle of the lateral aspect of the body of the humerus. When all its fibres contract simultaneously, the deltoid is the prime mover of arm abduction, the movement away from the midline of the body.

Another example, the ST11 adult individual exhibits a very strongly developed, and very unusual, coracoid tuberosity on the lateral part of both clavicles. The conoid process is also slightly developed. In addition, both shoulder blades show bony developments on the coracoid process. The coracoclavicular ligament serves to connect the clavicle with the coracoid process of the scapula. It consists of two parts, the trapezoid ligament in front, which inserts into the coracoid tuberosity, and the conoid ligament behind (Fig. 9). Since this tuberosity is strong, it means that the trapezoid ligament of ST11 was powerful. Other strong insertions can be observed on other bones, for instance on both ST11 radiuses.

To conclude, the results of the MSM examination, especially the coracoid tuberosity and the conoid process of both clavicles as well as the coracoid process of the shoulder blades of ST11, seem to indicate that the Spiennes people could have been involved in hard physical work which is compatible, among other possibilities, with mining activities.

6.5. How did the human bones arrive in the mine shafts?

In an attempt to understand the reasons for the introduction of the skeletons into the ST11 and ST6 shafts an elimination procedure was adopted.

a) The various causes of *unintentional introduction* have to be rejected:

- Various indices advocate against a mining accident. Indeed, the first bones of the adult skeleton of ST11 appeared at 4 m in depth, in the middle part of the access shaft, above the exploitation level. Furthermore the stratigraphy of ST11 does not show significant collapses in the shaft walls. Such an initial position of the corpse implies an arrival after the end of mining operations. In ST6, the bones were also discovered in layers posterior to the mining operations. Finally, the bones found in ST11 and ST6 do not show traces of fracture on fresh bone.
- An accidental fall in the shafts is equally unlikely in the absence of fracture on fresh bone.
- There is no evidence of animal intake. There are no bite marks.
- There is also no evidence of an introduction of the body through sedimentary processes from outside the shafts, for example, a mud or

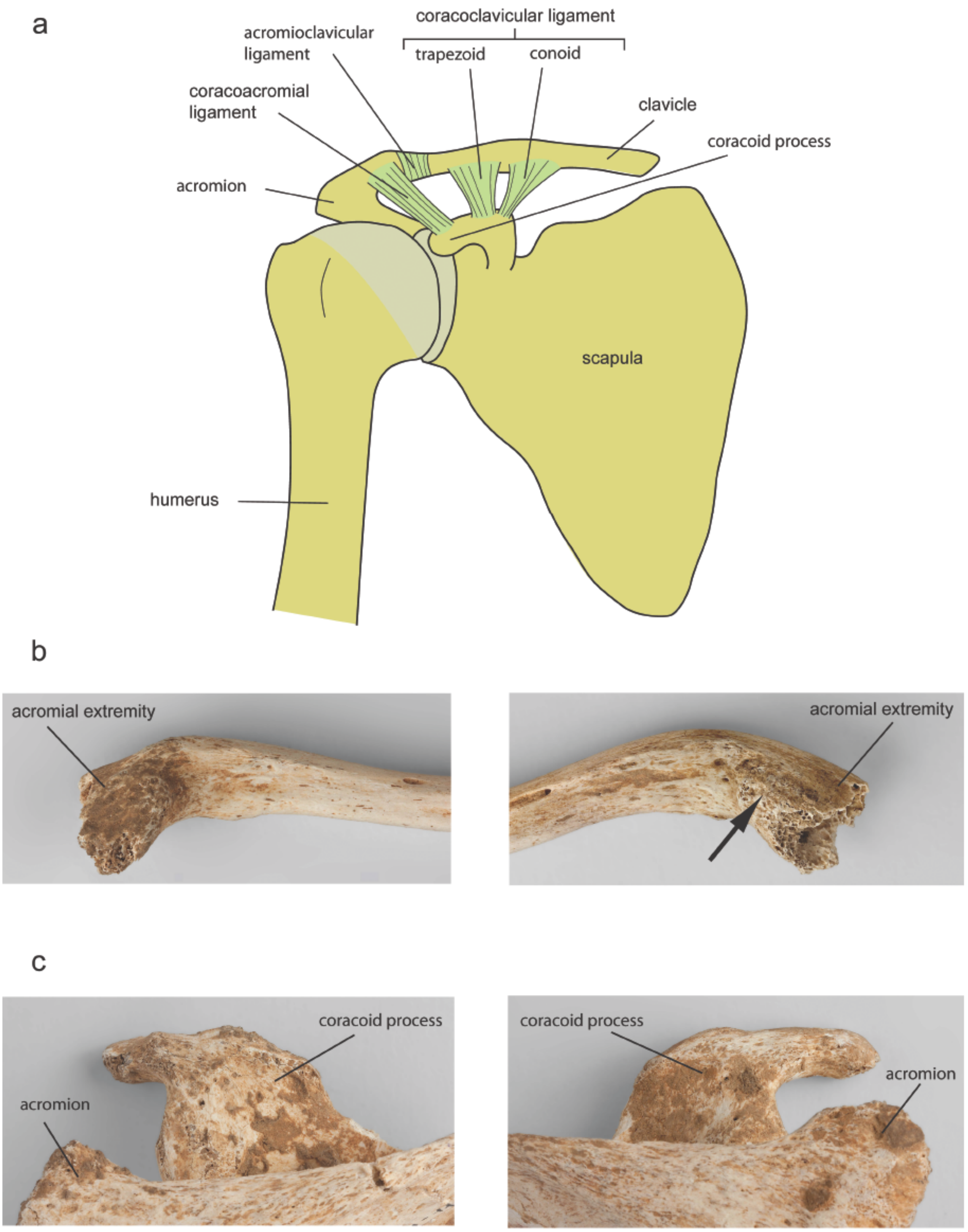

Fig. 9 – Musculoskeletal Stress Markers; a: theoretical front view of a right scapula, clavicle and humerus, with representation of some of the ligaments involved on the 'Petit Spiennes' ST11 skeleton, b: left and right ST11 clavicules, c: left and right ST11 scapulae with the coracoid process and the acromion process.

water flow that would have reworked a burial that was originally constructed on the ground surface near the mine shafts.

b) In the absence of any argument suggesting an introduction without human intent, it is legitimate to consider that the bodies were deliberately introduced into the ST11 and ST6 mine shafts. The question then arises as to whether such an introduction was of a burial nature or not.

b 1) An *anthropic non-sepulchral introduction* can result from a variety of causes:

- The corpse may have been considered as waste and thrown into a shaft during the backfilling process, without any sepulchral intention, for example after a fight, a crime or an execution; the bones of the ST11, adult and newborn skeletons, and those of ST6 show no signs of violence in favour of this hypothesis;
- The elimination of residues of cannibalism is also not conceivable for ST11 and ST6 because of (1) the anatomical connections and the almost intact preservation of the majority of the shafts of the long bones; (2) the absence of cutting incisions on the skulls and long bones of the skeletons and (3) the absence of fractures characteristic of fresh bones on both adult skeletons;
- The introduction of the bodies into the mine shafts could also reflect their rejection by the society, a sort of banishment of corpses, a voluntary act ('relegation graves') but without the violence of execution or cannibalism. In the cases of ST6 and ST11, such an interpretation is possible but is not directly demonstrable.

b 2) *Burial*?

Some indications of possible funerary gestures are observable for the adult skeleton of ST11. This includes the flexing position of the legs on the thighs and the possible flexion of the right forearm. These positions of the long bones of the upper and lower limbs on the left side is compatible with the foetal disposition of many prehistoric burials, notably Neolithic; by contrast, in the case of ST6, the strong dispersion of the bones prevents any discussion on this specific point.

Such a sepulchral interpretation of ST11 fits in well with the general context of the anthropological discoveries formerly made in Spiennes; and indeed, the relative frequency of more or less complete skeletons on the mining area, all deprived of any trace of violence, could indicate that the practice of burial, was present in the mining area (mainly 'Spiennes D and E' of DE HEINZELIN *et al.*, 1993).

On the other hand ST11 did not deliver any obvious grave goods accompanying the deceased; the flints and fragments of red deer antler tools found nearby the human bones could result from mining and knapping activities. It should be noted, however, that the presence of grave goods is not an essential condition for the recognition of a burial site; in the Meuse Basin, a few dozen kilometres east of Spiennes, the majority of the hundreds of Neolithic burial sites in karst environments deliver very few if any artefacts associated with the bones (TOUSSAINT, 1995, 2009).

So is ST11 an intentional burial or not? As none of the listed clues are decisive, it is difficult to conclude with certainty. The combination of these indices could be in favour of the burial hypothesis but a banishment of corpses by societies is also possible.

7. Conclusion and prospects

Human bones have been regularly discovered in the Neolithic mining site of Spiennes since the first researches undertaken in the 19th century, both in the shafts themselves and in the large workshops that overcome them. Some of these bones are more or less isolated; others come from relatively complete skeletons.

However, most of the anthropological discoveries made so far are ancient and have yielded little precise data on stratigraphy and spatial relationships between discoveries, and evaluating the possible sepulchral nature of these discoveries is challenging. The importance cannot be overemphasised of the recent excavations which, mainly in 1997-1999 and 2014-2019, produced many bones belonging to three individuals, two in the ST11 shaft and one in the ST6; indeed these new discoveries yielded numerous stratigraphic, archaeological, anthropological, chronological or archaeozoological information.

However, they are far from solving the numerous questions raised by the human remains of the site, in particular as regards the reasons why the bones were introduced into the filling of mine shafts.

In this respect, the detailed analysis makes it possible to reject an unintentional introduction of skeletons into the shafts. Among the intentional causes, the majority of those that are non-sepulchral (crime, cannibalism...) do not apply to the bones of ST11, and possibly to those of ST6; in this category, it is only possible to evoke a banishment, a rejection by society. In the current state of research, sepulchral intentionality is also an entirely possible hypothesis.

It is highly likely that there are still many human remains to be discovered in the Neolithic mining site of Spiennes. Indeed, some excavations have been limited; thus, for example, only the upper part of the shaft excavated in 1965 has been explored and it is quite possible that at least some of the other bones of the skeleton are present in the filling of the lower part of the shaft. The same situation could prevail for the skull discovered in 1953 by J. Verheyleweghen, as indeed for many previous findings carried out in the 1920s. Moreover, the number of anthropological discoveries compared with the number of features excavated since the 19th century in Spiennes is not so few, contrary to what has sometimes been believed (COLMAN, 1957). From this point on and to the extent that it is estimated that up to 20,000 shafts were dug on the site throughout the Neolithic period, it is more than evident that future research will still yield many anthropological discoveries which should shed light on the biological and cultural aspects of the miners of Spiennes. Such findings, which will not fail to integrate the latest developments in research methods, will also enable us to better understand the causes of the introduction of human remains in mining by enriching the corpus of the bones recorded with maximum accuracy, the decoding of which is mainly based on the recent findings of 1997-1999 and 2014-2019.

Finally, the anthropological analysis of the human bones of Spiennes has so far not developed its full potential. What remains now is to develop a biological approach based on the most recent techniques in, amongst others, palaeogenetics and biogeochemistry. DNA analysis could not only refine the determination of the sex of the deceased; it could also determine whether the newborn and adult found in the ST11 shafts are related, or whether the ST6 and ST11 skeletons have a family relationship. Ongoing geochemical analyses are being conducted to assess the nature of the food supply (C & N) or possible population displacements (N). Indeed, it is clearly by combining the results of archaeology, geology, classical anthropology, archaeothanatology and geochemical and genetic analyses that it will be possible in the near future to better understand the significance of all the discoveries of human bones made at Spiennes in the past 150 years.

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Flint sourcing revisited, the Bergerac (France) and Obourg (Belgium) cases

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Abstract

Studies on the origin of lithic raw materials have become increasingly important since the 1980s. Sourcing studies play a key role in appreciating territory management and group mobility, which are two major issues of the archaeology of prehistoric hunter-gatherer societies. Most approaches use only part of the potential information contained within archaeological lithic material. The improvement in our understanding of the nature of flint and its formation processes has allowed our interdisciplinary research-group to refine the methods used for its characterisation. A major aspect of this new approach is the 'evolutionary chain of flint' concept. Our work opens up new research directions such as the analysis of flint artefact surfaces which complements the taphonomic approach to archaeological sites in terms of assemblage integrity and site formation processes. We present here preliminary results of ongoing petrographical and geochemical analyses of geological flint samples from Bergerac (France) and Obourg (Belgium). Our approach aims to establish the geological history of flint prior to its collection by humans and to characterise the successive events which affected lithic artefacts after they were discarded. The multi-technical and multi-scale approach presented in this paper appears to be particularly applicable in reconstructing the litho-spaces of archaeological sites in order to contribute to more definition of prehistoric territories.

Keywords: flint, petro-archaeology, flint characterisation, evolutionary chain of flint, raw material sourcing, Bergerac, Obourg.

Résumé

Les études sur l'origine des matières premières lithiques ont gagné en importance depuis les années 1980. Elles jouent un rôle clé dans l'appréciation de la gestion du territoire et de la mobilité des groupes, deux enjeux majeurs de l'archéologie des sociétés préhistoriques de chasseurs-cueilleurs. La plupart des approches classiques n'utilisent qu'une partie de l'information potentielle contenue dans le matériel lithique archéologique. L'amélioration de notre compréhension de la nature du silex et de ses processus de formation a permis à notre groupe interdisciplinaire d'affiner les méthodes utilisées pour sa caractérisation. Un aspect majeur de cette nouvelle approche est le concept de « chaîne évolutive du silex ». Nos travaux ouvrent de nouvelles pistes de recherche telle que l'analyse des surfaces des artefacts en silex qui complète l'approche taphonomique des sites archéologiques en termes d'intégrité des assemblages et de processus de formation des sites. Nous présentons ici les résultats préliminaires des analyses pétrographiques et géochimiques en cours des échantillons géologiques de silex de Bergerac (France) et d'Obourg (Belgique). Notre approche vise à établir l'histoire géologique du silex avant sa collecte par l'homme et à caractériser les événements successifs qui ont affecté les artefacts lithiques après leur abandon. L'approche multi-technique et multi-échelle présentée dans cet article semble être particulièrement applicable à la reconstruction des litho-espaces des sites archéologiques afin d'apporter plus de définition aux territoires préhistoriques.

***Mots-clés** : silex, pétroarchéologie, caractérisation du silex, chaîne évolutive du silex, approvisionnement en matière première, Bergerac, Obourg.*

1. Introduction

During the past decade, the study and characterisation of lithic raw materials have become increasingly important for the reconstitution of the subsistence economies of prehistoric humans. However, this interest is not new since researchers organised themselves to advance the research about silicites at the 'Flint symposium' at Maastricht in 1969. The following national and international conferences have covered numerous aspects of knapped stone raw materials including geological origins, mining, uses and laboratory analyses (ROOS *et al.*, 1971; SÉRONIE-VIVIEN & LENOIR, 1990).

The present short paper focuses on methods that may be used to distinguish between materials as well as on characterisation studies of specific raw material sources. Ultimately, the objective of our approach is to improve reconstructions of prehistoric technological decision-making and land-use/mobility strategies (e.g. DELVIGNE *et al.*, 2019).

2. METHODOLOGY

Most provenance studies use only a part of the potential information contained within geological samples and archaeological lithic objects. The classical petrological (MASSON, 1981; SÉRONIE-VIVIEN & SÉRONIE-VIVIEN, 1987) and geochemical methods (SIEVEKING *et al.*, 1972; BRESSY, 2002; SHACKLEY, 2008; MOREAU *et al.*, 2016) are based on the assumption that research on primary sources is archaeologically meaningful. However, this questionable assumption requires methodological adjustments and needs to take into consideration the concepts we developed over the past ten years (FERNANDES & RAYNAL, 2006; FERNANDES *et al.*, 2007); these are twofold: 1) a dynamic petro-archaeological methodology and 2) a dynamic geochemical methodology.

They both allow the association of the petrological and geochemical approaches in a reasoned way. Indeed, whether the diagnostics are petrological or physico-chemical, they require a high level of consideration to be given to the alteration processes generated by the redistribution of materials in the environment, processes which radically modify certain aspects of geomaterials in their role as archaeological objects (BESANÇON, 1982; HARDAKER, 2012). The methodologies are built on the notion of an 'evolutionary chain' of flint, which is a conceptual and methodological renewal, based on interdisciplinary and multi-scalar approaches, which together eliminate many dead ends in terms of sourcing siliceous materials (FERNANDES, 2012).

Our method of raw material characterisation is developed over a series of different scales. It is based upon the evolution of the mineralogical composition by using optical microscopy, scanning electron microscopy (SEM) and Raman spectroscopy; to this base is added the evolution of the microfacies characteristics identified using microscopy and SEM analysis, on the transformation of porosity established using image analysis and porosimeter readings, and on the presence and distribution of trace elements using LA-ICP-MS, XRF, Raman spectroscopy and SEM-EDS on both the surface and subsurface of geological and archaeological samples. The textures and chemical compositions are ruled by pedological processes and sedimentological environments to which the specimens have been subjected and tabulating these provides a reference catalogue for specific facies.

Silicites (flint, silcrete, chert and other siliceous rocks) are metastable materials in surface environments (THIRY *et al.*, 2014): their structures evolve as a function of the various environments through which they pass and each step of their travel is recorded by a particular physico-chemical signature. Primary flint may experience different geological pathways and travel through very different environments before its collection and use in prehistory. The distinct alterations that occur between different sedimentary contexts must be taken into consideration since they are the components of a single, phased and correlated sedimentary system.

Analysis of the pre-depositional surfaces of samples allows several petrographic facies and textures to be recognised. Micromorphology reveals the petrographic facies and textures of the object's surfaces. The spatial arrangement of these surfaces is the key to deciphering their respective transformations and the succession of environments through which the flint passed (Fig. 1).

Archaeologically, analysis of the post-depositional surfaces complements taphonomic studies. This research axis focuses on deciphering the chronology of post-depositional processes on objects (after their abandonment in an archaeological site). Once decoded, these characteristics become discriminating elements for reconstructing the histories of lithic objects. The effects induced by mechanical, physico-chemical or biochemical processes, connected to the indices of human activity therefore become complementary supports to a classical taphonomic approach.

This method is based on three observation grids for flint evolution, petrography, gitology and taphonomy, applied to the relevant stages, which leads to the construction of a database that delivers results of direct interest to archaeologists: the origin of raw materials, techno-economic behaviour of the users and the integrity and chronology of the archaeological units of a site.

3. RESULTS

We present preliminary results of ongoing petrographical and geochemical analyses of geological samples of the Campanian Bergerac flint from Dordogne (France) and of the Campanian Obourg flint from Mons Basin (Belgium).

After an analysis (binocular and SEM) of the surfaces of the Campanian V limestone flint collected in secondary deposits in the alterites of the Montclard Forest (Bergerac, Dordogne, France), the sequence of the processes that modified the surface and sub-surface are revealed. The zones of transformation at the periphery of the samples indicate a polyphased and polygenetic mineralogical and geochemical history. The variability of compositions of the cortical and endocortical zones is more extreme than variations in the inner zone. Observable from the periphery to the inner zone are:

- a high porosity in the external neocortex with megaquartz, chalcedony and iron-rich clays;
- an inner neocortex with a lower porosity, low iron content, petaloid quartz and chalcedony spherolites;
- an interface (or endocortical zone) with a strong porosity, poor in quartz, composed of chalcedony and clay with iron compounds;

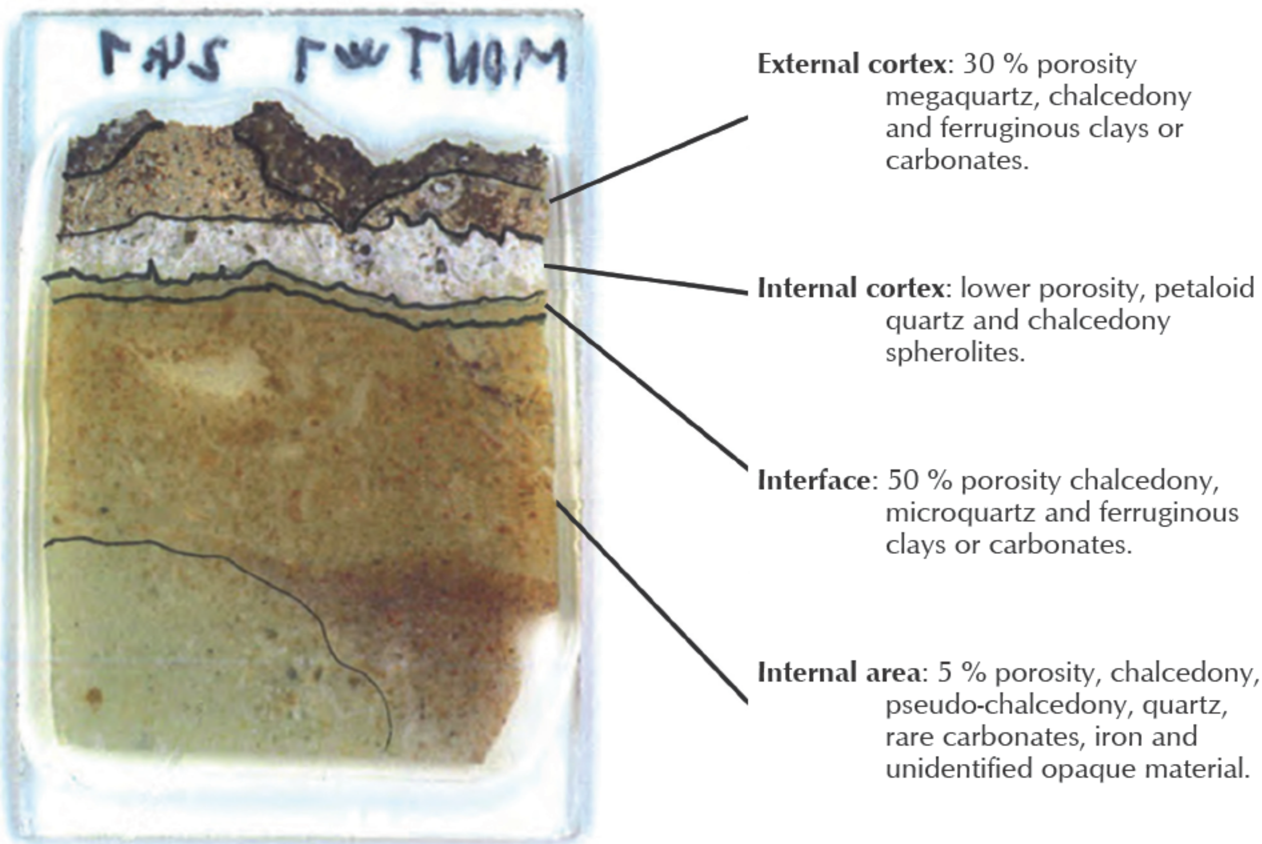

Fig. 1 – Commented thin section of a geological sample from Campanian flint (so called 'Bergeracois flint') from the 'clays with flint' at Forêt de Montclard (Dordogne, France).

- and finally, an internal zone, rich in chalcedony and pseudo-chalcedony, associated with detrital quartz grains, iron compounds and an unidentified opaque component.

Similarly, preliminary results of our analyses on Campanian Obourg flint derived from 'clays with flint' from the Mons Basin indicate that the distinction between cortical, endocortical and internal zones determined by LA-ICP-MS is again pertinent and useful. The chemical composition of cortical and endocortical zones varies considerably from that of the internal zone, regardless of the chemical elements taken into account. Interface 3 and the internal zone (Fig. 2) correspond to the same zone (primarily flint quartz and chalcedony) while 'interface 2' is a transitional zone, and 'interface 1' corresponds to a circulation zone of very high porosity, siliceous dissolution and recrystallisation processes.

From these observations, we conclude:

- the external cortex corresponds to dissolution processes and the recent acquisition of certain compounds;
- the internal cortex is characterised by the acquisition of various compounds, dissolution and recrystallisation processes;
- the composition of the internal zone does not vary greatly but, progressively, becomes significantly different from the signatures of the external and internal cortex.

4. CONCLUSION

Flint undergoes several transformations that allows its provenance to be traced across the landscape and that the alteration of its cortex/lithoclase must be considered as a temporal record of different pedological events. Given this perspective, the study of secondary, pre- and post-depositional transformations contributes to the identification of sources where raw materials have been collected by prehistoric humans and permits the degree of integrity of archaeological sites to be assessed. The multi-technical and multi-scalar approach initiated for Bergerac and Obourg flints appear to be particularly efficient in reconstructing the litho-space of each

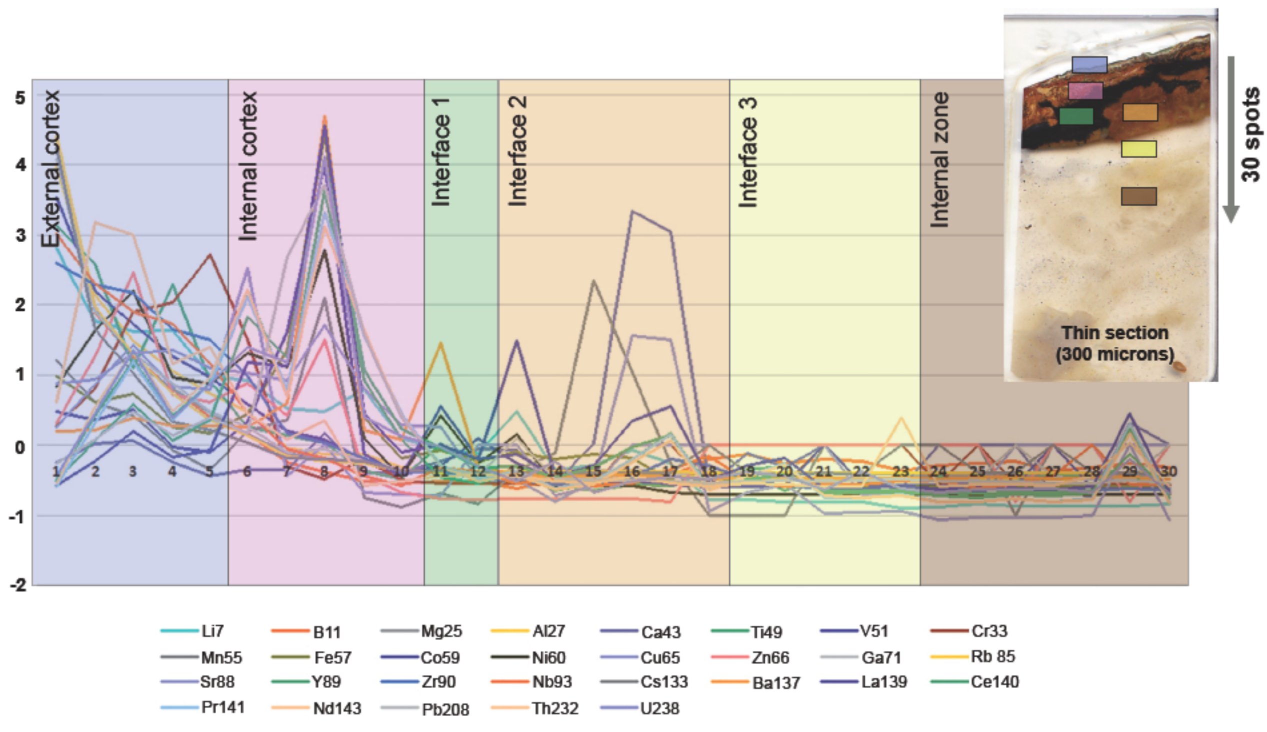

Fig. 2 – Geochemical analysis on Campanian flint from Obourg (Prov. Hainaut, Belgium), derived from 'clays with flint'.

archaeological site, with a further objective being to create a refined understanding of prehistoric exploitative territories. However, recrystallised areas within the specimens indicate polychronic and polygenetic mineralogical and geochemical histories, showing that compositional variability between the cortical and endocortical zones is significantly more pronounced when compared to the internal zone. Therefore, geochemical measurements can only be conducted when there is certainty about the zone of the object that is being examined.

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Neolithic flint mines and quarries from Vaucluse (France): Assessment and review

Pierre-Arnaud DE LABRIFFE,
Adrien REGGIO & Pierre ANDRÉ

Abstract

Neolithic mines and quarries from Murs and Malaucène have been known since the beginning of the 20th century, mainly because hundreds of grooved mallets were discovered on these sites. These two mines are extremely important, on the one hand because of the size of the exploited areas (more than 250 ha each) and on the other because of the high quality of the remains which are preserved. Moreover during the Chassean period (4500-3500 BC) the raw material extracted in Murs and Malaucène was distributed all over the northwestern Mediterranean seashore and along the Rhone Valley. However, despite an early discovery, information available about flint extraction methods is still incomplete.

We will assess existing data, present the first results of our own work started in 2015 and outline the goals of the programme we aim to pursue.

Keywords: Mines, quarries, bladelets, grooved mallets, pits, shafts, workshops.

Résumé

Les mines et carrières de Murs et Malaucène sont connues depuis le début du XX[ème] *siècle, essentiellement pour les centaines de maillets à gorge découverts sur ces sites. Ces deux sites sont extrêmement importants, d'une part par l'étendue des exploitations reconnues (plus de 250 ha chacune) et d'autre part, par l'ampleur des vestiges qui y sont conservés. De plus, pendant le Chasséen, la matière première exploitée à Murs et Malaucène sera diffusée sur l'ensemble du pourtour de la Méditerranée nord-occidentale et le long de la vallée du Rhône. Toutefois, malgré une identification précoce, les données disponibles sur les modalités d'extraction pratiquées sur ces deux sites sont encore lacunaires.*

Nous ferons un bilan des données existantes, présenterons les premiers résultats des recherches que nous avons entamées en 2015 et les objectifs du programme que nous entendons poursuivre.

Mots-clés *: mines, carrières, lamelles, maillets à gorge, fosses, puits, ateliers de taille*

1. Introduction

The lower Rhone Valley is the source of much flint used since the Palaeolithic, and intensively exploited during the Neolithic period by mines and quarries (Fig. 1). The Lower Cretaceous levels (Bedoulian stage, part of the Aptian stage) from the Vaucluse contain high quality flint frequently called 'blonde flint'. It was extensively used in prehistoric times especially during the Middle Neolithic (Chassean period), and reused in Modern Times to make gunflints. At least four extraction areas are known in Vaucluse: Châteauneuf-du-Pape /Orange, Monieux /Sault, Murs and Malaucène (Fig. 1).

Flint outcrops located in Murs and Malaucène are known to have been exploited by mines or quarries since the end of the 19th century. The two others were identified more recently. Murs and Malaucène are considered to be the most important of the Vaucluse. To date, we still do not know much about these sites. Consequently we felt it was pertinent to restart research activities to try to better characterise them.

We shall begin by drawing together the current state of knowledge from an analysis of previous research combined with the results of our preliminary investigations. We shall also

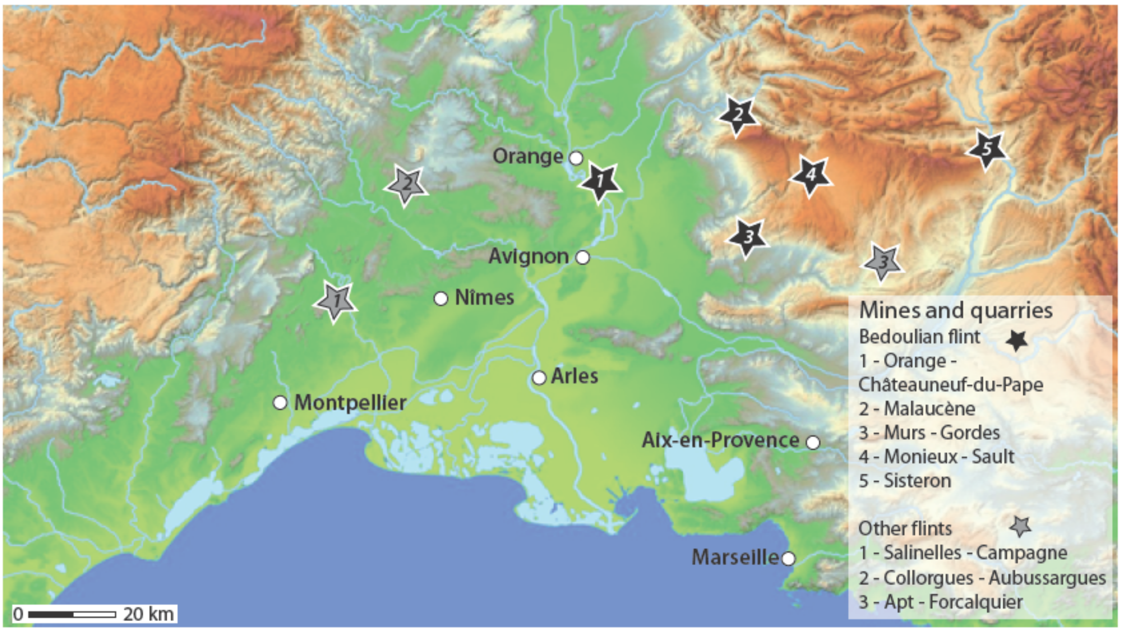

Fig. 1 – Maps of the flint mines and quarries from lower Rhone Valley and Provence.

develop proposals regarding the areas of future research which we would like to be able to develop within the framework of the programme which we have already begun.

2. LOCATION OF THE SITES, THE GEOGRAPHIC AND GEOLOGICAL CONTEXTS

2.1. Murs

The municipality of Murs is situated on the south side of the Vaucluse Mountains between 400 and 650 m in height, approximately 35 km east of Avignon. The territory presents contrasting landscapes of fields, orchards and wooded spaces. The mines and quarries that have so far been discovered are distributed on an arc about 7 km long, situated on the western side of the municipality (Fig. 2). They overflow slightly into the nearby municipality of Gordes to the South. The zones of extraction do not exceed 400 m in width, they are intermittent and cover a total area estimated at approximately 250 ha (Fig. 2). They are located on small plateaux, generally forested but sometimes cultivated, which overlook generally dry valleys.

The geology of Murs is complex, in particular because of the presence of numerous North-South aligned faults. Around the region lie siliceous formations from the Mesozoic era (Bedoulian, n5U3), and in the centre, there are Tertiary Oligocene deposits. Each of these formations contains some good quality flint, but only the Bedoulian levels were exploited.

2.2. Malaucène

The municipality of Malaucène is located on the northwestern slope of Mount Ventoux, around 30 km east of Orange. The main extraction zone is in the north-east of the municipality of Malaucène, near the hamlet of Veaux. This sector, called 'Plateau of Rissas', covers 1.5 km from east to west and also from north to south, providing a surface area of between 200 and 300 ha (Fig. 3). It is restricted to the north by the gorges of the River Toulourenc which has a steep south/north slope (height between 500 to 300 m). It is cut by about ten dry coombes, known as the 'Coombes of Veaux', between 30 m and 50 m deep. They are very narrow at their base, and open up to 200 m wide at their summit. Their slopes are often very steep or even vertical. It is in these coombes, on the bottom, along the slopes and at the summit, that evidence of flint exploitation is most important.

There are also zones of extraction beyond the Plateau of Rissas, in particular in some coombes on the right bank of the Toulourenc River. They are located within the municipality of Mollans-sur-Ouvèze (Drôme) and in the 'Grande Combe', in the municipality of Malaucène, east of Rissas (Fig. 3). This whole zone, between the Drôme and Vaucluse, forms the Veaux Basin which covers approximately 1000 ha. Today the vegetation consists mainly of scrub which is difficult to penetrate. There are also numerous scree slopes where the vegetation is absent.

The geology in the Veaux coombes is restricted to a single layer of Urgonian limestone (n5U3). In the Veaux basin, on both banks of the Toulourenc River, this unit is overlain by the Burdigalian limestone.

3. History of research

3.1. Early 20th century grooved mallet 'hunting'

From the end of the 19th, and more particularly at the beginning of the 20th century, numerous amateur prehistorians explored the quarries of Murs and Malaucène, their main interest being the acquisition of grooved mallets. These were collected by the hundreds (Fig. 11-13). Their discovery generated a plentiful literature peppered with intense debate about the age of these objects.

However, these pioneers of prehistory quickly made the connection between the tools, the vast workshops in the middle of which they were found, and the acquisition of flint. After a visit to Malaucène, Dr. Paul Raymond gave one of the first descriptions of the mining evidence. He describes '*important open-cast mining or in the form of shafts. There is not only a workshop, but still quarries where the raw material was extracted, rough-hewed and partially shaped* (...). *We meet there* (...) *colossal accumulations of fragments of flint, flint flakes, mixed with fragments of the calcareous rock* (...). *To give an idea of the importance of these cuttings* (...) *A coombe* (...) *showed two banks of fragments covering its natural hillsides and having not less than about thirty metres in height and about twenty wide at the base. These banks* (...) *consist only of flint debris, flakes, more or less finished tools, hammerstones, and lastly mallets.* (...) *This important exploitation of flint occupies a considerable area* (...)' (RAYMOND, 1905, p. 18). He does not hesitate to compare this site to Spiennes but also to several other mines in the North of France.

In his article of the 1930s summarising his work on the municipality of Murs, André Vayson-de-Pradenne gives a very edifying description of what he saw in the first years of the 20th century: '*a visit to the sites was then really striking; we saw at the same time at the scene the enormous mass of the waste from flint knapping and the number of extraction tools proportionate to this mass, still in place, as if the old quarrymen had left the work a few years previously*'. He adds that '*the fragments of split and partially crushed limestone mixed with the waste of the flint reaching in places a thickness of about two metres*' (VAYSON-DE-PRADENNE, 1933-1934, p. 147).

All the researchers of this time were impressed by the extent of the quarries which they investigated and by the mass of evidence. A. Vayson-de-Pradenne summarises things well by evoking '[the] *first signs of the modern industrial spirit*' (VAYSON-DE-PRADENNE, 1933-1934, p. 178). This intense pioneering research ended with World War I.

3.2. 1920-1970, the search for the settlements of the quarrymen

After this pioneering craze, interest in these sites becomes blurred. Between the 1920s and the beginning of the 1970s there was nevertheless some work on the quarries of Malaucène. The research question then was to establish where the settlements of the quarrymen were and what they were like. To try to answer this, limited excavations were carried out in the 'Grotte du Levant de Leaunier' and in 'Abri Grangeon', both found in the heart of the extraction zone.

The 'Grotte du Levant' opens into the coombe of Leaunier, half way up the slope. It is a

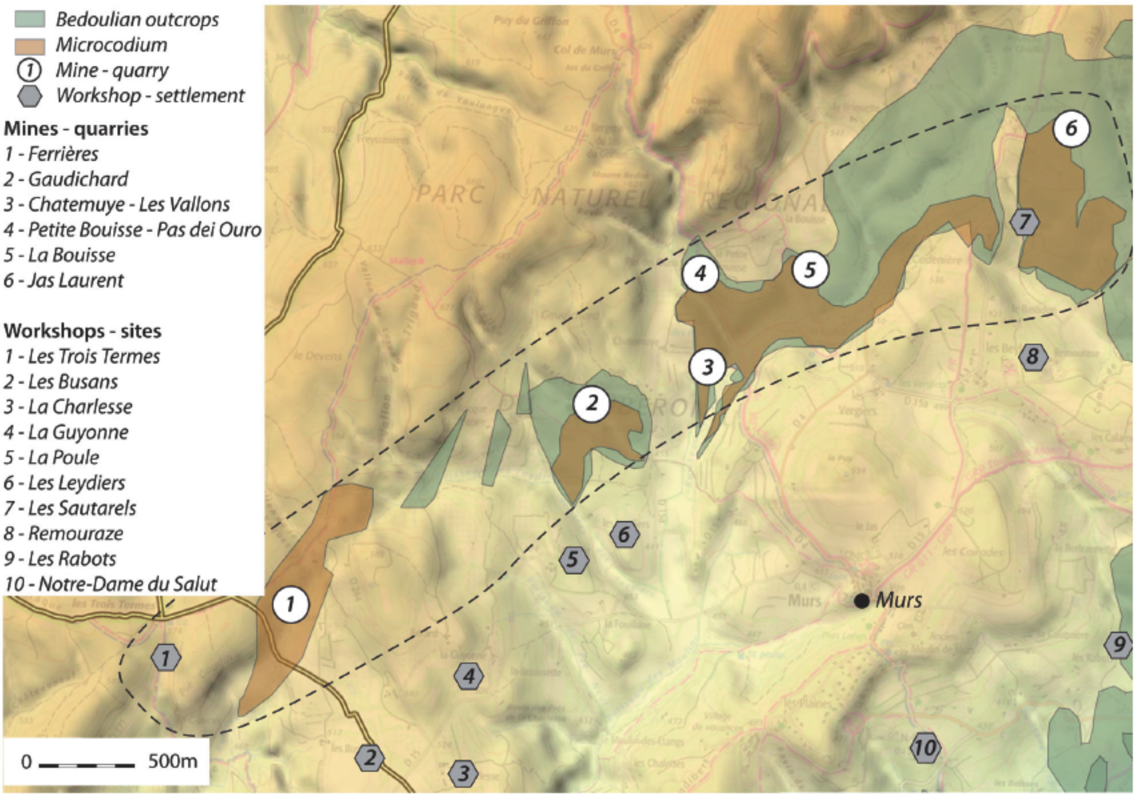

Fig. 2 – Murs, location of the sites.

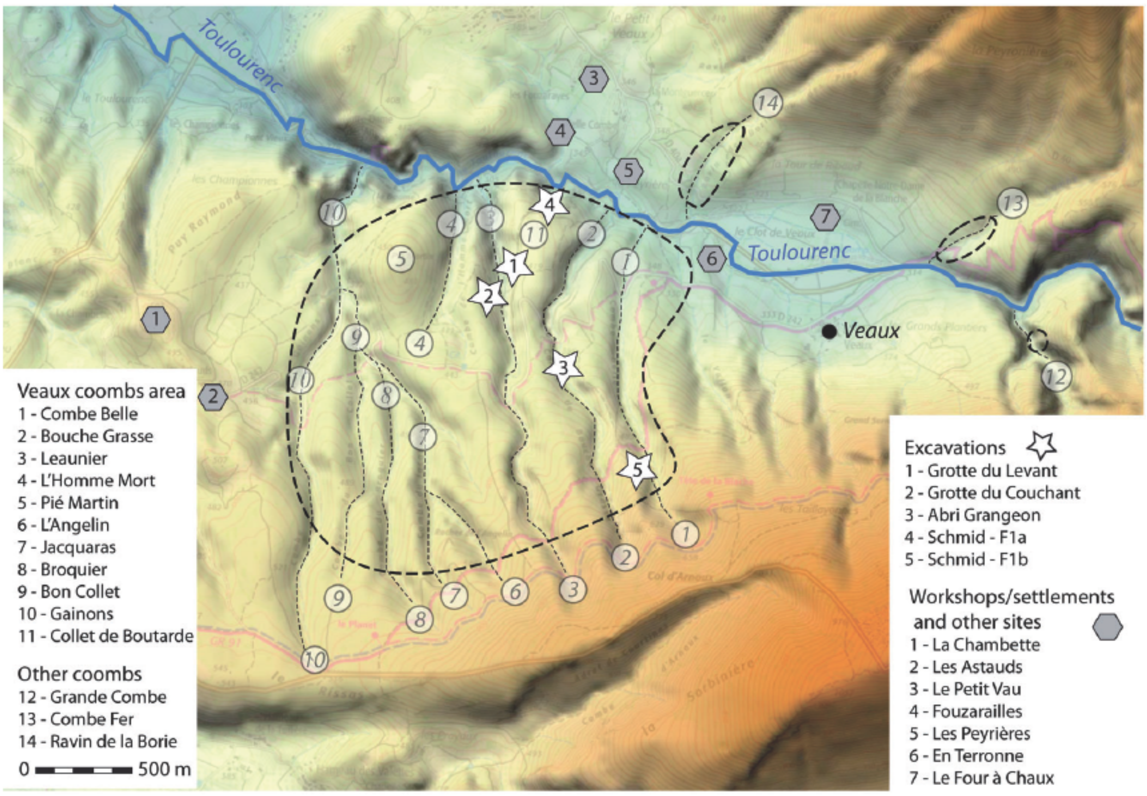

Fig. 3 – Malaucène, location of the sites.

cavity of 13 m x 7 m, with a maximum height of 2 m. It was excavated by the brothers Louis and Auguste Catelan between 1920 and 1922 (CATELAN & CATELAN, 1921, 1922), by Louis Gauthier in 1953 (GAUTHIER, 1953) and Albert Barthélémy between 1956 and 1959 (BARTHÉLÉMY, 1952-1956, 1955). The substratum was never reached in spite of archaeological probings 3.8 m deep. Seven stratigraphic levels were identified by A. Barthélemy (Fig. 4). They were an alternation of layers containing vestiges of extraction with other layers showing signs of apparent domestic use. They revealed occupation spanning the Middle Neolithic to the Final Bronze Age (BARTHÉLEMY, 1952-1956; BUISSON-CATIL & VITAL, 2002, p. 213). The Chassean culture was very strongly represented.

The 'Abri Grangeon' (7 m x 3 m, with a maximum height of 2 m) is located in the base of 'Bouche Grasse' coombe. It was almost totally excavated by Jean Vincent between 1966 and 1970 (VINCENT, 1966; VINCENT & DUBOIS, 1972). Its spoil heap has been re-excavated and sifted recently (ANDRÉ, 2013; ANDRÉ & LÉA, 2013). In spite of excavations to 1.8 m deep the substratum was not reached. The stratigraphical sequence contains eight layers, some consisting of blocks of limestone, sometimes compacted, corresponding extraction waste, and others containing quantities of ash or with clay deposits dominant (Fig. 5).

At both sites an important number of artefacts were collected.

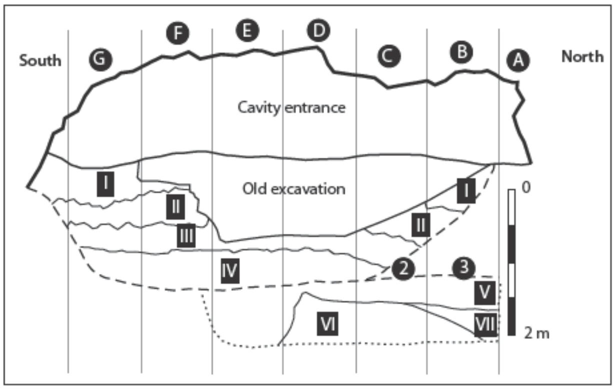

Fig. 4 – Malaucène 'Grotte du Levant de Leaunier', cross-section. After BARTHÉLÉMY, 1952-1956.
Layer I: Modern use of the cave (sheepfold; gunflint workshop);
Layer II: Dispersed limestone and flint nodule fragments;
Layer III: Black sediments (probable hearths) and archaeological material (ceramics, blades and bladelets);
Layer IV: Extraction and knapping activities, presence of 'knapping waste concentrations', but 'without nice blades, pottery, fireplaces, bones';
Layer V: Black unconsolidated sediment (ashes and charcoal indicating possible hearths, ceramic sherds and bone fragments);
Layer VI: Extraction and knapping activities, 'cemented deposit with dust made from flint and limestone', flakes;
Layer VII: Extraction and knapping activities, 'unconsolidated deposit', 'rubbles, mixed with yellowish clay', numerous flakes, tools and bones.

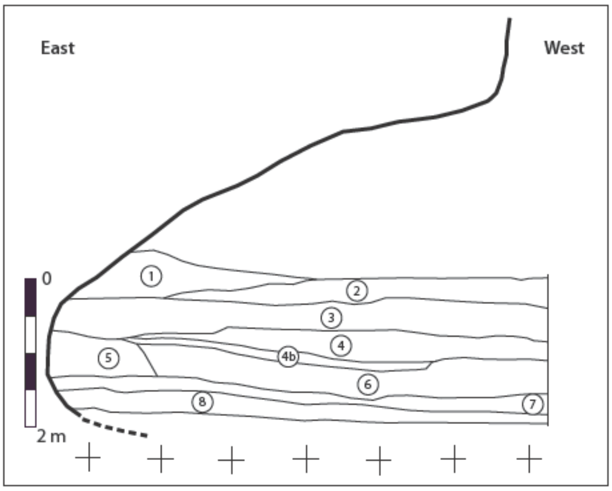

Fig. 5 – Malaucène 'Abri Grangeon', cross-section. After VINCENT & DUBOIS, 1972.
Layer 1: Rubbles originating from the walls;
Layer 2: Limestone nodules and brown sediment;
Layer 3: Limestone blocks (8-4 cm) and numerous large black flint flakes;
Layer 4: Ash rich deposit (hearth), small burnt limestone blocks and numerous artefacts (struck flint, ceramic, bones);
Layer 4b: Layer of brown compacted sediment with only few artefacts and stones;
Layer 5: Limestone blocks from the vault or from the outside, partly cemented;
Layer 6: Same as layer 5 but less consolidated and with some artefacts;
Layer 7: Layer with ashes and burnt limestone blocks, few flint flakes;
Layer 8: Clayey compacted sediment.

3.3. 1950-1960, mines and quarries, the rebirth of interest

In 1959, then again in 1962, Elisabeth Schmid undertook two excavations at Malaucène on the vestigial remains of the mining features. She published two articles (SCHMID, 1960, 1963) and a synthesis (SCHMID, 1980). Published in German, these works were not influential in France, although Jean Courtin mentioned them because of his appointment to oversee her excavations (COURTIN, 1974, p. 187-188).

The excavation F1a was opened in 1959 at the foot of the plateau of 'Collet de Boutarde'. E. Schmid had initially planned to dig out a trench of 9 m in length and 1.5 m in width. Facing technical difficulties, she finally limited her trench to two test pits. The stratigraphy was divided into two main phases: in the first metre is evidence of gunflint production, below which is up to 3 m of waste produced by Neolithic extraction. The substratum was not reached. The Neolithic layers consisted of limestone rubble mixed with flint flakes.

The excavation F1b was opened in 1962, in the high part of 'Combe Belle', perpendicular to the valley. It is a trench of about 15 m in length and 7 m of maximum width, and 6 m deep. 170 m^3 of material was removed during the excavation consisting solely of waste produced by Neolithic extraction. This contained a large number of flint flakes, no tools, but a half-dozen broken mallets. At the base of the trench a small part of the calcareous substratum was revealed.

It is from these two limited excavations that E. Schmid proposed the reconstructions that she published in the Bochum catalogue (SCHMID, 1980, fig. 152, fig. 158). These plans were well received and sparked interest amongst the community of mining archaeologists (Fig. 6).

3.4. 1980-2000, the *chaînes opératoires*

From the middle of the 1980s Didier Binder, and then Vanessa Léa, proposed the first typo-technological analysis of Bedoulian blonde flint industries (BINDER, 1984; LÉA, 2004a). They highlighted complex *chaînes opératoires* which include the heat treatment of the flint, an identification of blade and bladelet debitage by indirect percussion or by pressure flaking. The whole mining operation appeared to facilitate a large scale production of standardised blades and bladelets during the Chassean period (4500-3500 BC).

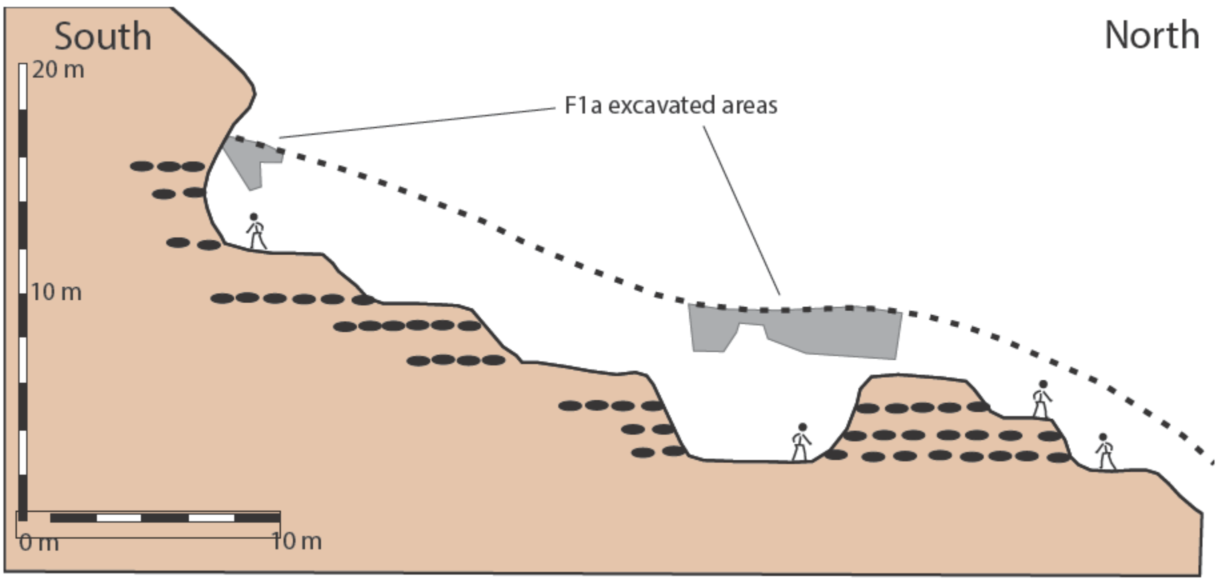

Fig. 6 – Malaucène, extraction diagram. After SCHMID, 1980.

3.5. From 1990s, raw material and lithothecas

Several researchers and teams now study the raw materials of Murs and Malaucène (AFFOLTER, 2002; BARBIER, 1996; BINDER & GUILBERT, 1996; FERNANDES, 2013; WILSON, 2017). There are a number of samples kept in different lithothecas. It is important to mention that there have been two attempts at characterisation by chemical methods (ASPINAL *et al*,. 1976, 1979; BLET *et al.*, 2000). In both cases it has proven the difficulties to differentiate between the Bedoulian flints of Murs and Malaucène.

3.6. Turn of the millennium, networks and diffusion

Following the analysis of the *chaînes opératoires* and the raw material, the distribution networks were then analysed. These studies, led by Didier Binder and Vanessa Léa, showed that bladelets made from the Bedoulian flint of Vaucluse were distributed by networks extending for several hundred kilometres. They are found in Liguria, in Catalonia and in the Toulouse area (BINDER, 1998; LÉA *et al.*, 2004; VAQUER, 2012) and as far as the Valais region of Switzerland (HONEGGER, 2011).

In the Toulouse hinterland and in Languedoc, both finished products and cores were distributed, some not heat-treated, whereas in the most distant regions, such as Liguria and Catalonia, it is the finished products which are more often present including unheated blades, heated bladelets and arrowheads.

3.7. Today, a return to the processes of acquisition of raw material

In recent decades and in spite of the interest in the production of Bedoulian flint from Vaucluse, the extraction sites, the procurement

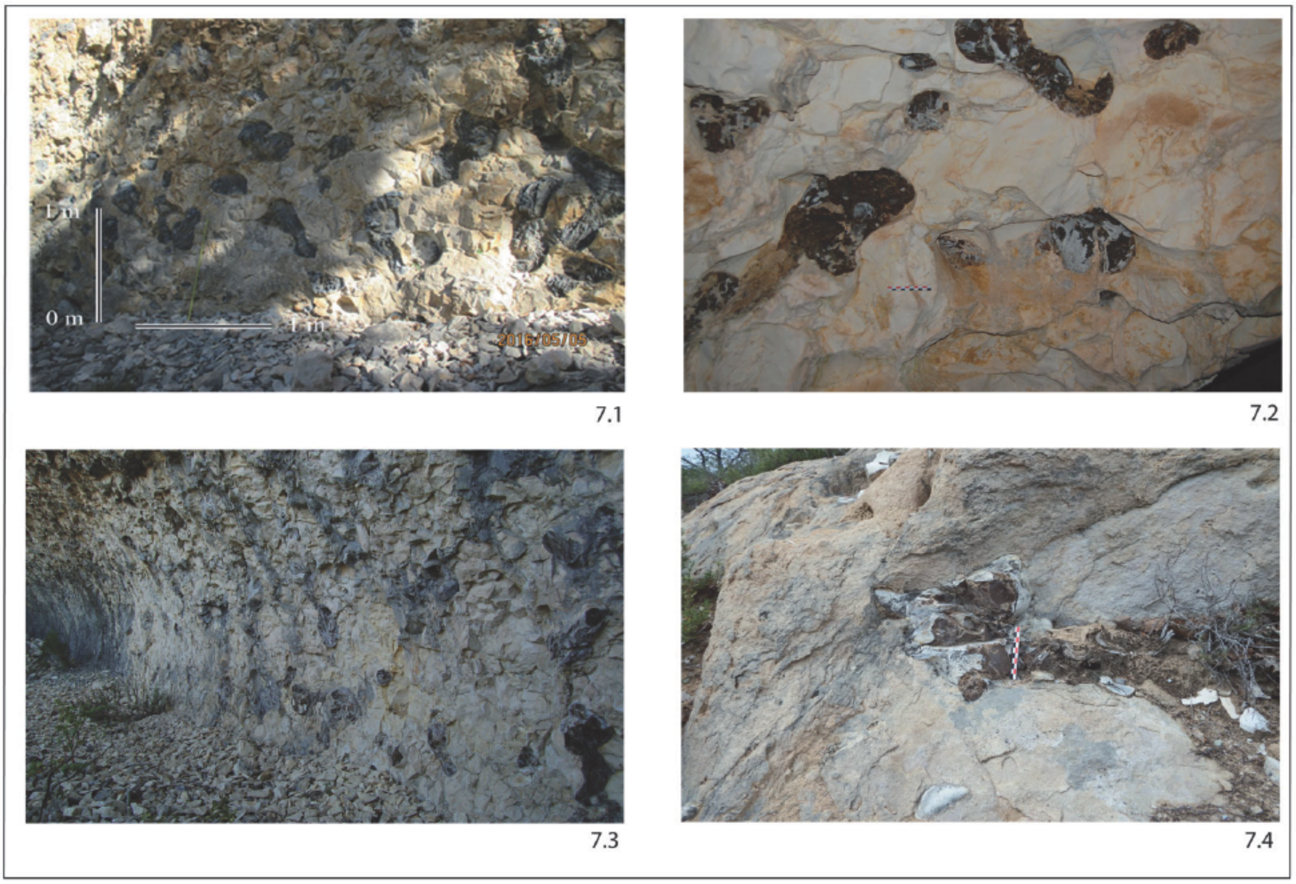

Fig. 7 – Primary flint nodule deposits. 1. Malaucène 'Grande Combe'; 2. Malaucène 'Grotte du Levant'; 3. Malaucène 'Combe de Leaunier', face; 4. Murs 'Chatemuye/Les Vallons'.

and the preparation of the raw material have not been studied extensively. Schmid's work still remains the most important reference.

All available documentation, including articles, reports and archives, were first gathered and analysed during the course of 2014. The first field work began in the summer of 2015. Our goal was to rediscover the sites and evidence mentioned by our predecessors and to establish an overview of these settlements and their main characteristics, the outcome of which was to define a set of research questions and to plan further investigations.

4. ACCUMULATED KNOWLEDGE

4.1. Raw material and bedrock

4.1.1. Bedrock

The bedrock consists of bioclastic limestone with flint of Lower Cretaceous. This

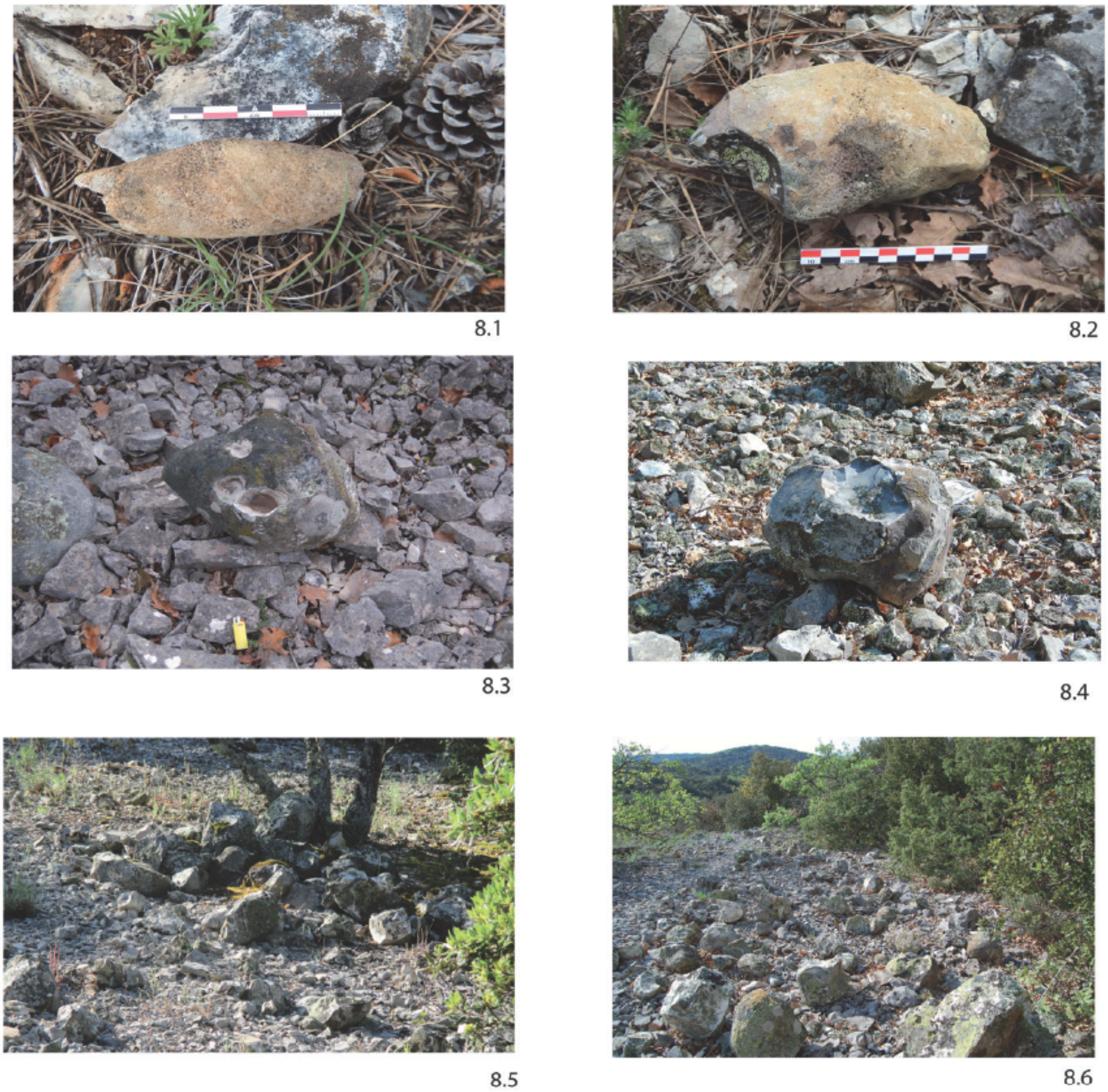

Fig. 8 – Morphology of the flint nodules. 1. Murs 'Le Vallon'; 2. Murs 'Jas Laurent'; 3-4. Malaucène 'Bouche Grasse'; 5. l'Angelin'; 6. 'Bouche Grasse'.

limestone belongs to the base of the Bedoulian (sub-floor of the Aptian). They are of similar facies to that of the Urgonian. We noted strong variations in the consistency of the rock, which is sometimes very compact, sometimes faulted and jointed. In Murs we noticed that there is a narrow correlation between limestone with microcodia and the quarries. Indeed, microcodium aggregates loosen the limestone and make it easier to break which favours the extraction of the flint nodules.

4.1.2. Arrangement of the raw material

In Murs as in Malaucène, the siliceous horizons are irregular and complex. In Malaucène, there are tabular formations situated at the top of the limestone pavement on the Rissas plateau which dominate several metres of the underlying rocky spurs. These formations provide outcrops of poor quality material, very often faulted and inconvenient for knapping.

We identified outcrops which could qualify as 'pockets' of flint. They consist of a multitude of flint nodules sometimes arranged up to several metres in height. They can be very compact as in the 'Grande Combe' at Malaucène (Fig. 7: 1) or, in contrast, much wider as on the right bank of the coombe of Leaunier at Malaucène (Fig. 7: 2-3) or on 'Chatemuye/ Les Vallons' at Murs (Fig. 7: 4). These areas were generally intensively exploited.

4.1.3. Size and morphology of the flint nodules

The geological layers of Malaucène frequently contain spherical flint nodules about 40 cm in diameter and sometimes more (Fig. 8: 3-4). In contrast, on the right bank of the Toulourenc River, the flints are pebbles about 10 cm long. In Malaucène River, there are also some flints with quirky shapes, as evidenced by broken protuberances found on site.

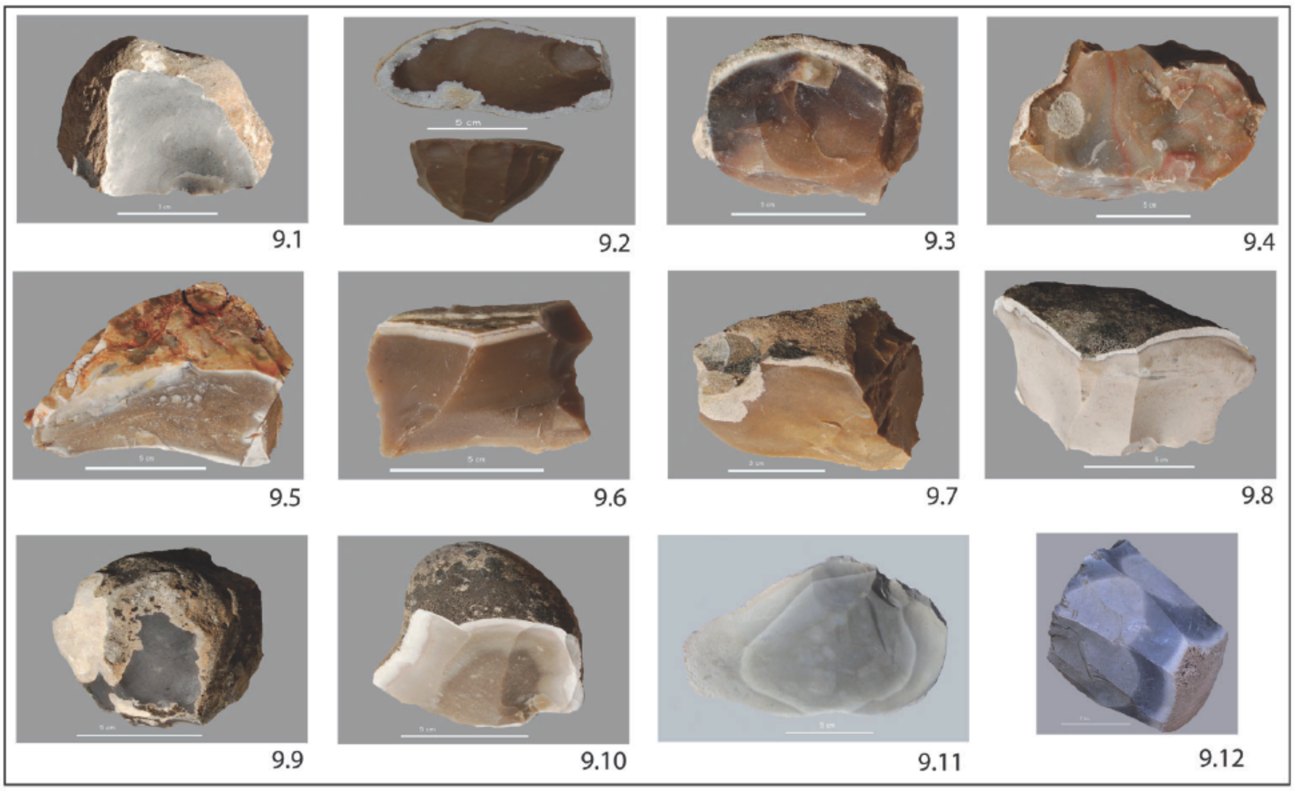

Fig. 9 – Variability of Malaucène's raw material. 1. 'Bouche Grasse'; 2. 'Combe des Gainons'; 3-4. 'Combe de l'Homme mort'; 5. 'Dessus de Leaunier'; 6-9. 'Leaunier'; 10. 'Vallon de la Borie' (Mollans-sur-Ouvèze); 11. 'Combe de Jacquaras'; 12. 'Combe de Bouche Grasse'.

In Murs, nodules are usually ellipsoid but there are also some which are spherical (Fig. 8: 1-2). They are present in different sizes. The largest can reach up to 30-40 cm in diameter, the smallest being 5 cm in diameter. The majority of the flints that are still visible today are roughly between approximately 20 and 30 cm. Some Bedoulian flints occur in tabular layers, but it is of rather mediocre quality, being very faulted and jointed.

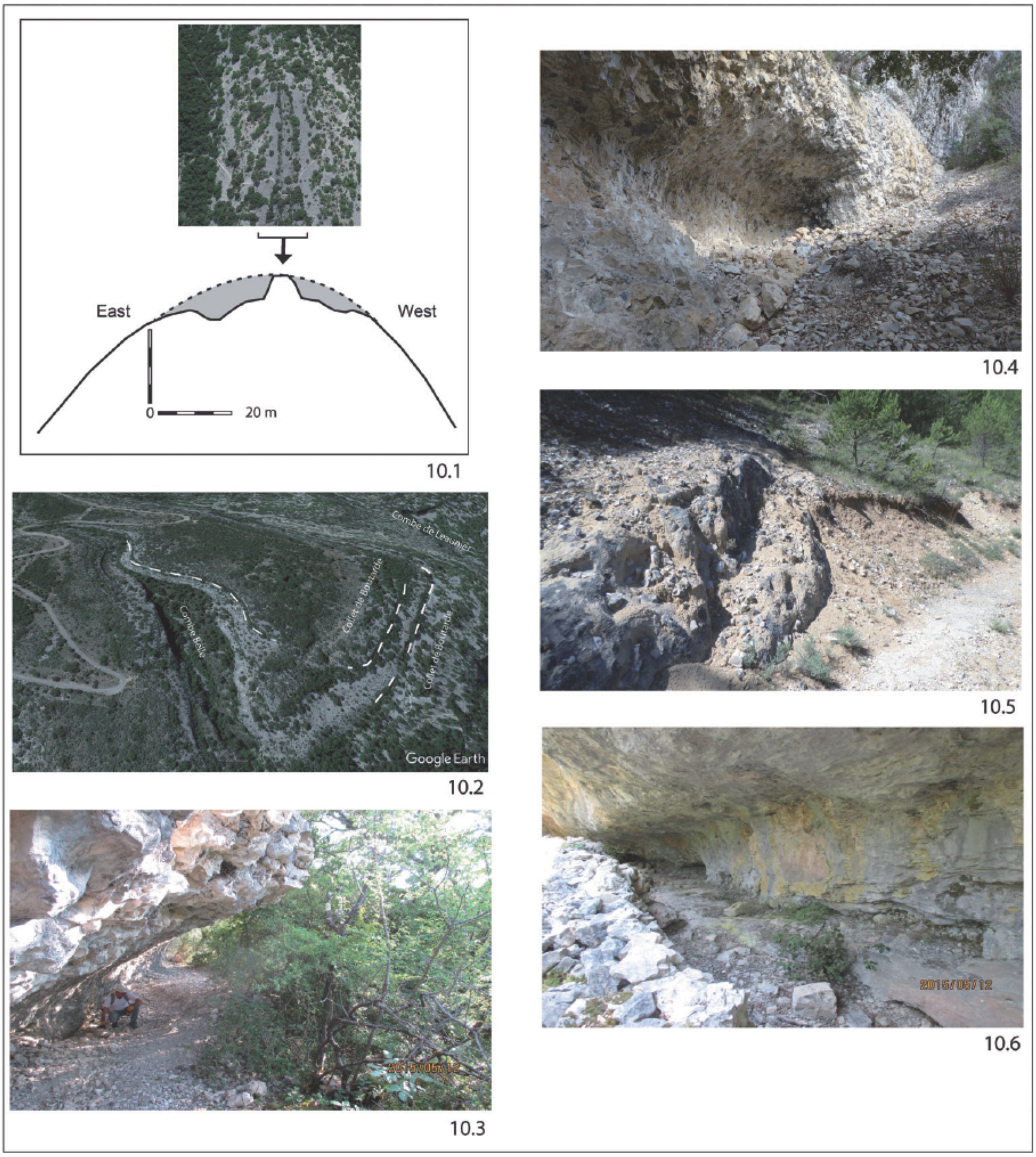

Fig. 10 – Extraction remains and techniques.
1. Malaucène, between 'Combe Belle' and 'Bouche Grasse', residual ridge of rock. After SCHMID, 1980; 2. Malaucène 'Collet de Boutarde': working face showing steps; 3. Malaucène 'Combe de Leaunier', undercut quarry; 4. Malaucène 'Grande Combe', big extraction niche; 5. Murs les Vergiers', steps; 6. Malaucène 'Abri Gangeon II', undercut quarry.

4.1.4. Nature of the flint

The Bedoulian flint of Vaucluse shows a great variety of colours, textures and cortices (Fig. 9). The observations recorded in the coombe of 'Leaunier' show that there is a blonde flint, similar to the one that served to make the Chassean bladelets. There are also banded materials, and flint of other colours ranging from white to dark grey. In Malaucène, in the upstream parts of the coombes of 'Combe Belle', 'Bouche Grasse' and 'Leaunier', the flint is grey or blue-grey, sometimes with clearer spots. In other coombes, the flint ranges from dark brown to red and from honey coloured to deep burgundy, sometimes in zones and often with inclusions of quartz. In the right bank of the Toulourenc River the flint is speckled beige. The flint of the 'Grande Combe' is grey-black to black. The colours of the flint from Murs are also varied. They range from light brown to dark brown and to almost black.

4.2. Extraction techniques

The quality of preservation of the sites of Murs and even more so at Malaucène, is in every respect exceptional. We can still see today numerous examples of evidence of Neolithic activity, virtually in the state in which sites were abandoned by Neolithic people. This is because the area has never been cultivated, for the most part, and has been little frequented since the end of prehistory. This state of preservation still allows us to visualise the work of the miners. The work was so intensive in many places that they totally remodelled the landscape. On both sites we were able to note the implementation of several different techniques of extraction.

4.2.1. Quarry

Flint exploitation was frequently undertaken by quarrying vertical faces which cut the exposed rock. These faces could develop concave walls and significant overhangs. The most spectacular are in the 'Collet de Boutarde' and at its meeting point with the 'Combe de Leaunier' (Fig. 10:3). The 'Abri Grangeon', in the coombe of 'Bouche Grasse', is also a good example of an overhanging face (Fig. 10:6). In certain parts, as in 'Collet de Boutarde' the succession of vertical faces of different heights forms a series of terraces several metres high (Fig. 10:2).

On the crest separating 'Combe Belle' from 'Bouche Grasse' close to the trench (F1b) made by E. Schmid, there is a small ridge of rock of some metres in width and height that can be followed for more than 100 m. This is the last evidence of the Neolithic exploitation of a much wider cliff (Fig. 10:1). Those features can be compared to the Lousberg quarry in Aachen (WEINER & WEISGERBER, 1980, fig. 69).

The horizontal or dipping limestone layers which contain good quality material were exploited from the top. This technique was implemented in Murs (Fig. 10:5) and in a less obvious way in the coombes of the right bank of the Toulourenc River. This type of exploitation also creates terraces of modest size compared with those of the 'Collet de Boutarde'. These remnants are very similar to those documented and published by Gerd Weisgerber in Oman (WEISGERBER, 1997).

4.2.2. Pits or shafts?

Depressions were identified by several of our predecessors. Francki Moulin writes: '*a demonstration is especially remarkable at Malaucène [it is] these depressions, [which are] regularly circular, are generally outlined in the mass of waste* (...). *These adjacent depressions, like a set of basins are each 8 to 10 m in diameter, of variable depth, but generally small, appearing in series, arranged longitudinally in the base of the plateaux itself, which they partially follow*' (MOULIN, 1905, p. 74-75). Dr Raymond also comments on them: '*Some places intrigued [us] initially. They are depressions in the form of cupules, regularly circular, some of them are hardly 2 to 3 m in diameter and their depth is insignificant; but there are others which measure 8 to 15 m in diameter with a depth of 3 to 5 m*' (RAYMOND, 1905, p. 21).

We easily identified these depressions. They are more numerous than was formerly estimated. In the coombes of Veaux, these depressions are distributed in several zones which cover vast areas. We also located them in the quarries of Murs, in 'Jas Laurent', 'Ferrières', 'Bouisse' and in

'Petit Chatemuye'. In Murs they are apparently less numerous and harder to discover because they are situated under forest cover. It is still difficult today to know if they are big pits, as envisaged by E. Schmid (SCHMID, 1980, fig. 152, and Fig. 6 in this paper) or the entrance to shafts.

4.2.3. Subterranean extraction

Two cavities have been known for a long time in the quarries of Malaucène: the 'Grotte du Levant' and the 'Grotte du Couchant', both located in the coombe of Leaunier, inside the Rissas plateau. The first comprises only a single chamber today. The second consists of a small network of chambers. In each of these 'caves' the walls are dotted with big flint nodules and with numerous alveoli having previously contained flint.

The investigation and recording of the underground network of the 'Grotte du Couchant' was made in 2016. The accessible network consists of three chambers: the first one opens into the quarry whilst the other two descend inside the calcareous plateau. The first chamber is 13 m by 9 m and approximately 2.5 m in height at its highest point. Midway up the wall is an excavation rather similar to the niches found in flint mining shafts. Chamber three, the deepest, is more than 20 m long with a width between 3 m and 5.5 m. This chamber has a surface area of more than 80 m^2, and a height of more than 2 m. Both the walls and ceiling retain numerous flints as well as many cavities and hollows which demonstrate that raw materials were taken.

The 'Grotte du Levant' is part of the continuation of one of the faces of the 'Collet de Boutarde', where the face is particularly concave. The limestone walls outside the 'cave', as well of those of the 'cave' itself, abound in flint. The digs revealed that several of the layers of infill consisted of mining waste (limestone rubble, fragments of nodules, flint flakes).

Both of these cavities may be partially or even totally artificial, and may represent large extraction chambers. It should be recalled that it is around these caves, in this sector of the Rissas plateau, that the flint used extensively during the Chassean period was most probably extracted.

4.2.4 Firesetting

In Murs, Neolithic people deliberately chose to exploit flints which were in limestone loosened by the presence of microcodium. At Malaucène the limestone is very compact, so the bedrock could have been purposefully weakened by firesetting to allow easier fracturing and the recovery of flint nodules. This technique has been identified at other flint extraction sites, in particular in Kleinkems (WILLIES & WEISGERBER, 2000).

There are certain evidences for the existence of firesetting in Malaucène. E. Schmid claims to have observed in the F1b excavation burnt blocks of limestone surrounded by copious quantities of charcoal (SCHMID, 1963, 1980). Her observations were echoed by J. Courtin (1974, p. 189-191) and L. Willies and G. Weisgerber (2000, p. 143). For our part, we also noticed that certain faces, in particular that of the 'Grande Combe' in Malaucène, showed traces of fire or signs suggesting thermal cupules (Fig. 10:4).

4.3. Extraction tools

The extraction tools identified consist mainly of mallets or hammers (Fig. 11). Several hundreds of these objects were previously collected both in Murs and in Malaucène. They are mainly made from pebbles of quartzite collected from the former Pliocene terraces of the Rhone or the Durance rivers, tens of kilometres away. There are also some limestone mallets (Fig. 11:5) and more rarely mallets in diorite (Fig. 11:4), serpentine or eclogite and even sandstone (D'AGNEL, 1902; CARIAS, 1920; Fig. 11:7).

Their weight can vary from some hundreds of grams to more than 12 kg, with the average weight between 3.8 kg and 5.3 kg (RAYMOND, 1905; COURTIN, 1974, p. 188). They are mainly grooved, more rarely with two grooves, parallel or crossed. Rather than grooves the mallets sometimes feature lateral notches. We noticed a large variation in the finish of these tools, some being particularly well shaped, while other pebbles were almost untouched

There are also other types of extraction tools, far more rare made of flint. E. Schmid collected some during her excavations (SCHMID, 1960, 1963), as did Jürgen Weiner on the occasion of his visit to the coombes of Veaux in 1999 (WEINER, 2003, fig. 4).

4.4. Elements of flint production at the extraction sites

The preparation and the fracturing of the flints were made directly in the quarries. We noticed that in some places there were piles of flint nodules left as if they were about to be transported, worked on or knapped (Fig. 8:5-6). The artefacts visible on the surface consist mainly of cortical flakes, sometimes quite large. But there are also some finished products and exhausted cores. We envisage that certain parts of the *chaînes opératoires* were conducted on the spot. In particular, the long unheated blades may well have been manufactured on site, because

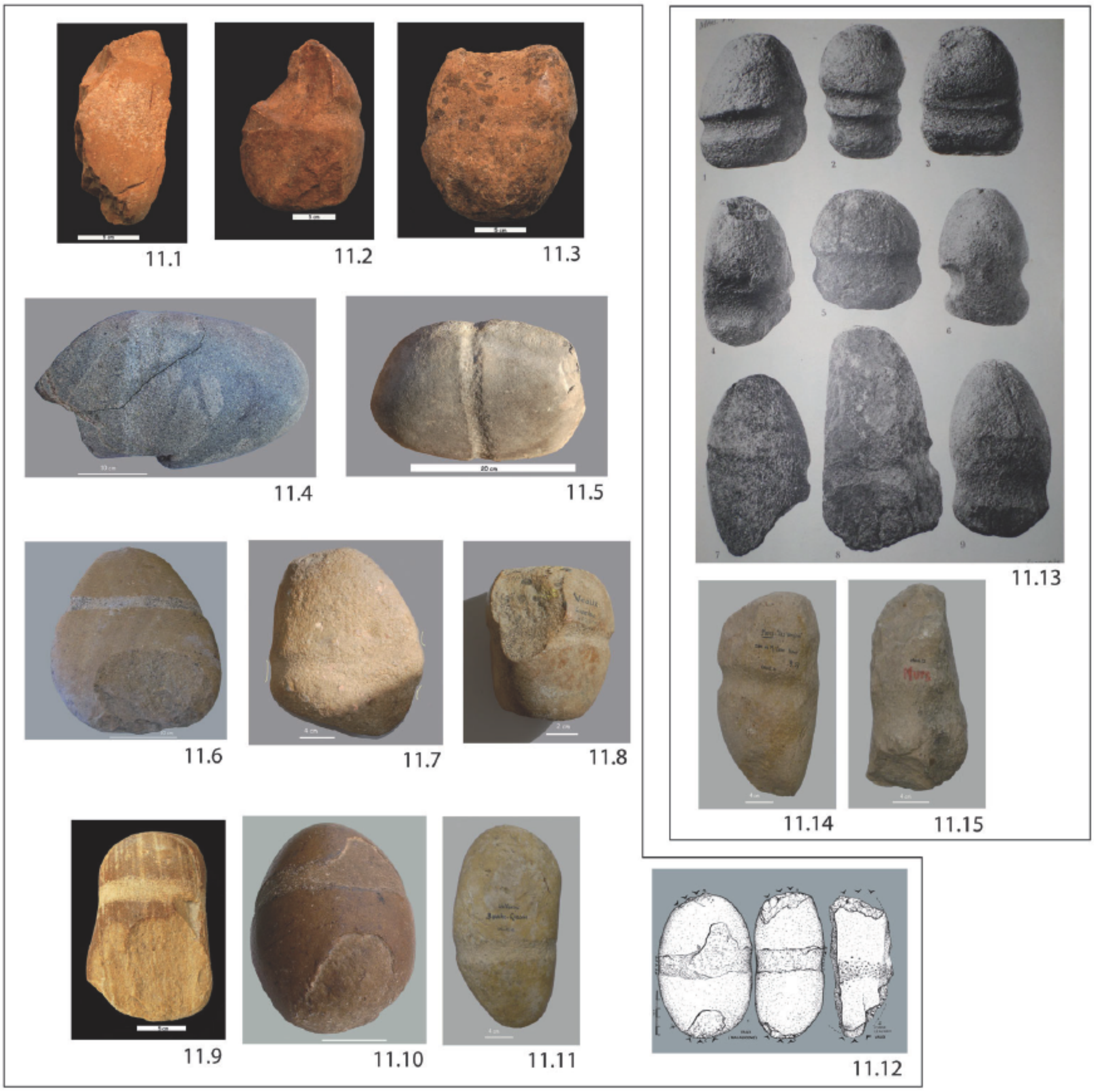

Fig. 11 – Mallets, extraction tools.
1-3. 'Grotte du Levant de Leaunier', Barthélémy collection; 4. 'La Chambette', diorite, private collection; 5. 'Combe Belle', limestone, private collection; 6. 'Bouche Grasse', Monge collection; 7. Sandstone, Guerold collection; 8. 'Combe de Leaunier', Guerold collection; 9-12. Veaux and Veaux Combes, Corbeille, Tournière, Gauthier, and Barthélémy collections. 13. After VAYSON-DE-PRADENNE, 1933-1934; 14-15. Gauthier collection; 1-12. Malaucène; 13. Murs

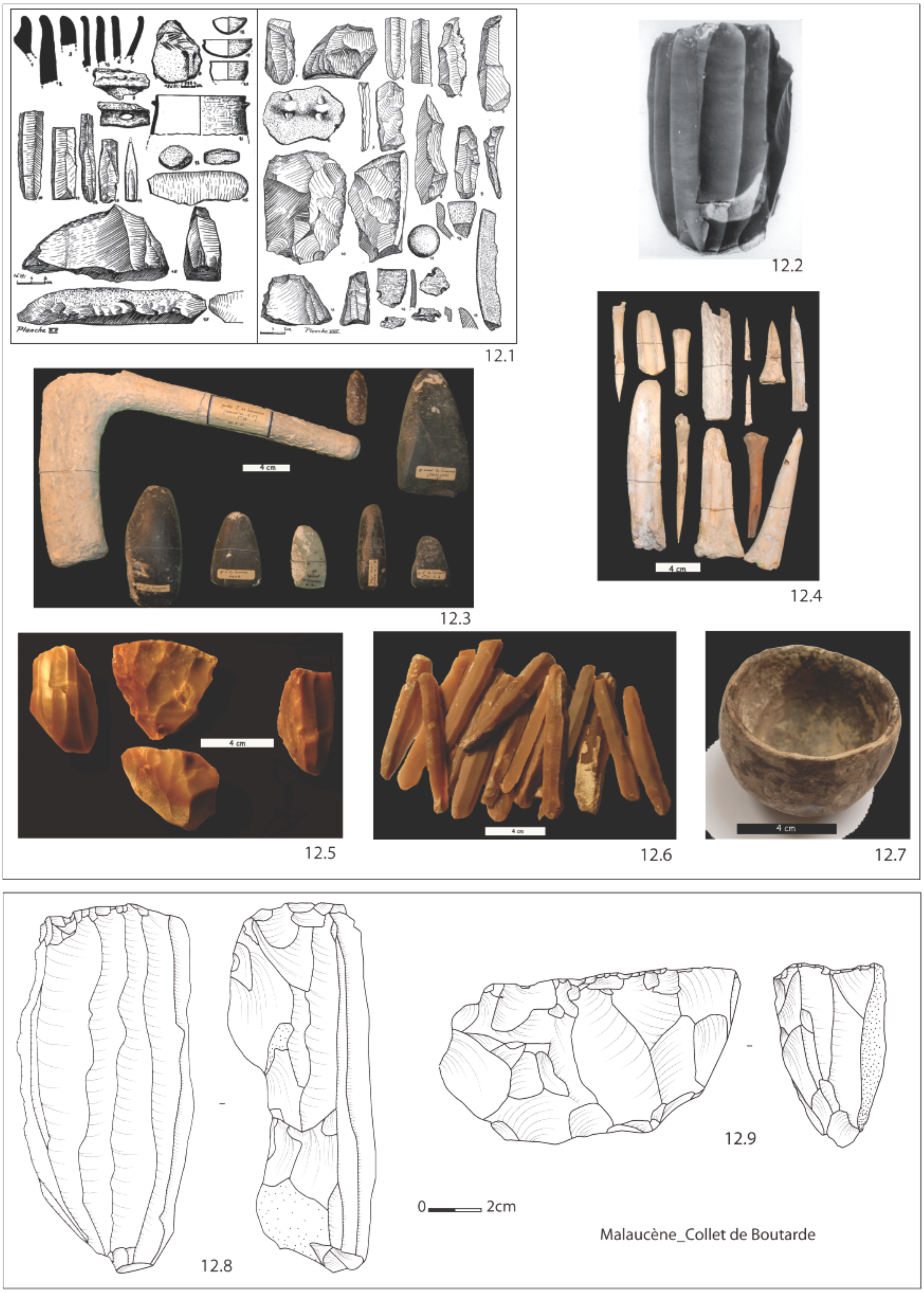

Fig. 12 – Artefacts.
1-7. Malaucène 'Grotte du Levant'. 1. After BARTHÉLÉMY, 1955, 1960; 2. Gauthier collection; 3-7. Barthélémy collection. 8. Blade core collected at Ferrières Quarry, Gauthier collection; 9. Preheated bladelet precore Malaucène 'Collet de Boutarde'.

we found some blade cores at both Malaucène and Murs. Heat treatment was also conducted on site as shown by the presence of some cores and flakes with mat and brilliant surfaces. Some of the finds made in the 'Grotte du Levant' and the 'Abri Grangeon', clearly show there was flint knapping in these locations because many cores, blades and bladelets were found (Fig. 12:2, 5-6).

4.5. Household activities at the mines

At present the extraction sites at Murs only shows evidence related to the activities of procurement and/or to the initial preparation of the raw material. However, located in close proximity is a number of settlements, recognised only by fieldwalking, which produced assemblages of very different artefacts from those usually found in a quarry or a workshop. At these sites there is no evidence of knapping activities but rather artefacts that were related to domestic use. On the site of 'Charlesse', for example, situated approximately 1 km from the quarries, Marc Deydier describes '[A] *rich site* (...) *characterised by polished stones, arrowheads, some willow or laurel leaf points*' (DEYDIER, 1904, p. 172). A. Vayson-de-Pradenne records that at 'Mourre de Bérard', a few hundred metres away from the extraction sites, there are '*Polished axes of green rocks, fragments of pottery, cores ..., bladelets ..., scrapers, tranchets, arrowheads* (...)' (VAYSON-DE-PRADENNE, 1933-1934, p. 175).

The excavations in the 'Grotte du Levant' and those of 'Abri Grangeon', in the heart of the extraction zones of the Rissas Plateau, yielded archaeological evidence indicative of activities not directly related to the extraction of flint. In the 'Grotte du Levant', the brothers Catelan and Barthélémy found dozens of cores, hundreds of unworked blades and bladelets, but also stone balls, beads, axes of green rock, fragments of querns, ceramics and animal remains (Fig. 12). In 'Abri Grangeon', J. Vincent collected 68 cores, 200 blades or bladelets, but also tools (scrapers, burins and arrowheads), 150 ceramic sherds and fragments of fauna.

The geographical area surrounding the Veaux coombes, within a radius of approximately 20 km, is dotted with small sandstone eminences with a high density of sites or indications of sites. There are settlements with workshops for pottery production and the heat treatment of the flint at Saint-Martin in Malaucène, for example, and dwelling sites in 'La Chambette' and 'En Terrone' (Fig. 3). There are also specialised workshops for the production of arrowheads such as those of 'Peyrières' in the municipality of Mollans-sur-Ouvèze (ANDRÉ, 2016).

4.6. Dating

We still do not have any 14C dates. Consequently, typo-chronological analysis is used to attribute date ranges to the items found at the sites of extraction, processing and consumption. In his synthesis on the Neolithic of Provence, J. Courtin envisaged that the quarries of Murs and Malaucène had been exploited since the Middle Neolithic and up to the 'Chalcolithic' (COURTIN, 1974). We think we can now propose a longer period of use.

The mines and quarries exploiting the Bedoulian flint at Murs and Malaucène could have started in the Early Neolithic during the middle of the 6th millennium. Indeed, important evidence of quantities of this raw material has been discovered at several settlements. Examples are the 'Baratin' in Courthézon (Vaucluse), and also in the region of Nice at Castellar 'Pendimoun', in Liguria at 'Arene Candide', and in western Languedoc at Sallèles-Cabardès 'Grotte Gazel' (BINDER, 1998).

During the Chassean period (4500 – 3500 BC), the Bedoulian flint is found in abundance in the archaeological collections of the South of France. This period represents the apogee of the use of Bedoulian flint. Blades, bladelets and cores, as well as the ceramic artefacts found in the 'Grotte du Levant' and in 'Abri Grangeon', point to the fact that this quarry was exploited during this period. The lithics and pottery found at 'Trois Termes' at Gordes, situated a short distance from the Murs quarries, are also typically (LÉA, 2004b).

The end of this period of mining exploitation is poorly documented. From the Late Neolithic (3500 – 3000 BC), bladelets of Bedoulian blonde flint are replaced gradually by longer blades of grey or grey-blue Bedoulian flint. The origin of this material is traditionally attributed to the deposits of Monieux/Sault. However, the upstream parts of the coombes of Leaunier, 'Bouche Grasse' and 'Combe Belle' produce a raw material of the same colour. Therefore we can speculate that the quarries of the Rissas Plateau continued to be exploited until the end of the 4th millennium.

The Murs and Malaucène quarries were exploited for a minimum of 1500 years between the middle of the 5th millennium and the end of the 4th millennium. However it is highly likely that they were exploited for a much longer period, one which could span more than two millennia, or even three, from the mid 6th to the end of 3rd millennium.

5. Synthesis and Prospects

5.1. Definition of the extraction area

At both sites the extent of the zones of extraction remains to be identified.

The coombes of Veaux undoubtedly constituted the main zone of extraction. 'Combe Belle', 'Bouche Grasse' and 'Leaunier' represent the coombes where there is a concentration of the most remarkable evidence connected to the extraction and the preparation of the raw material. However, coombes situated further west ('l'Homme Mort', 'Pié Martin', 'Rocher de l'Angelin', 'Jacquaras') also provide significant evidence of extraction (Fig. 3). The definition of the extraction zones in the most western coombes remains to be done. There are also isolated extraction zones such as that located in the 'Grande Combe', situated more than 2 km east of the hamlet of Veaux. On the right bank of the Toulourenc River, there are also signs of flint extraction in at least two coombes ('Combe Fer', 'Vallon de la Borie'). Finally, there may well be other zones of extraction still to be discovered further west outside the Veaux basin.

In Murs, we have so far identified about ten different zones, distributed on an arc 7 km long. It is likely that some of these sites, which appear to be separate today, could in fact be parts of a single site (Fig. 2). Put end to end they would cover a surface area close to 250 ha. However, the better definition of these zones and the identification of undiscovered sites still remain to be done.

5.2. The precise characterisation of geological deposits

It is possible that our fieldwalking expeditions failed to identify other important outcrops of raw material. If so, this was probably the consequence of two essential factors: either they are masked by the waste of later exploitation and vegetation, or they were completely removed by extraction. Much work remains to be done to identify flint deposits or layers.

The various sampling campaigns led by several early teams do not bring clarity to these questions. Partly because recording techniques were then less accurate, and partly because it is not clear whether the samples were taken from outcrops which were actually exploited during prehistory. Considering the diversity of the siliceous horizons, the number of samples is insufficient. In addition, the descriptions, the thin section analyses and the other types of analysis undertaken are still not widely available. It is thus necessary to collect and to synthesise all the existing geological data, and perhaps to relaunch a specific program of sampling at the various proven places of extraction.

In parallel, we intend to proceed to a detailed study of the limestone. The particular properties of the bedrock were a fundamental parameter which explains the techniques used by Neolithic miners. At Murs for example, the presence of microcodium was a determining factor in the opening of that extraction site.

5.3. More information about extraction techniques

It is also necessary to document the morphology of the various faces and the terraces and to locate and record all the depressions. A

Lidar survey was undertaken, but still needs to be processed.

During 2017, we have scheduled geophysical surveys in the quarry depressions found at Malaucène. The purpose of this is to determine if these depressions are simple pits or genuine shafts and to estimate their depth. We also hope that geophysics will be able to discriminate between the underlying limestone bedrock and extraction waste.

We also plan to explore the underground extraction networks of the 'Grotte du Levant' and the 'Grotte du Couchant'.

5.4. Extraction tools

Our first investigations revealed that a significant number of grooved hammers are held in several different collections. We have a potential corpus of several hundreds of these tools today. Until now they have neither been described nor analysed. Most of this work thus remains to be done.

5.5. Lithic production

Lithic production is still a significant field of investigation at these sites. Work is needed to determine the precise nature of the activities and to define the *chaînes opératoires*. We know that the testing and the fracturing of flints was carried out *in situ* but, we also discovered that there were other more advanced stages of the *chaînes opératoires* represented too. This is confirmed by the nature of some of the artefacts found in the 'Grotte du Levant' and in 'Abri Grangeon'. A detailed study of these archaeological assemblages remains to be undertaken. We also intend to survey the knapping waste material preserved within the quarries.

5.6. Vaucluse Mining complex

Several years ago the notion of a mining complex was proposed (DE LABRIFFE & THÉBAULT, 1995). In brief, this hypothesis aimed to study the relationships which may well have existed between contemporary settlements and the raw material procurement sites. It seems that the Vaucluse mines and quarries are particularly adapted to that kind of study because of their size and their environment. Indeed, these mining sites were exploited over a very long period of time. This suggests that the sustainability of these sites was a major consideration of the local Neolithic communities in this region. They were thus naturally at the centre of the territorial organisation of these Neolithic societies, more so than the megaliths, causewayed enclosures or dwelling sites. Indeed, we know of a significant number of contemporaneous sites in close proximity to the mines and quarries at Murs and Malaucène especially specialised workshops, dwelling and funeral sites. Combining this data should turn out to be particularly fruitful and allow us to better understand the nature of the relationships maintained between the various sites within this complex.

6. CONCLUSION

After visiting Malaucène in 1999, J. Weiner asked, provocatively and quite rightly: '*Why French archaeologists never showed any apparent interest in excavating in the flint mining area of Veaux*' (WEINER, 2003, p. 516). In answer to this, it is clear that the scale of the task was enough to scare off more than one researcher. However he was right and the quality, the interest and the importance of these sites certainly deserve attention. The collation of earlier data and our preliminary fieldwork is still a very modest contribution, but a necessary review of these impressive quarries has now begun. At this stage, we have only scratched the surface, as much more remains to be revealed. Many years of research and study are needed to enrich our understanding of these sites. We hope this paper will be the first of many.

Translated by Nuala Davies and Tim Brennand

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A jadeitite axehead in the midst of the famous Neolithic flint mines of Spiennes?

Michel ERRERA, Pierre PÉTREQUIN,
Hélène COLLET, Alison SHERIDAN & Ivan JADIN

Abstract

More than a century ago, Alfred Lemonnier, Director of phosphatic chalk quarries in the Mons region, donated a jadeitite axehead from Spiennes to the State among a small collection of 'knapped flint'. Originally, this artefact was 12 to 15 cm long. Several scientists tested various ways – destructive or non-destructive – to determine this green stone until they discovered their origin in the ultimate end of the Alps near Genoa (Italy), thanks to *Projet JADE*. But this raises a new question: how to explain the presence of an almost complete axehead of jadeitite in the midst of the flint extraction site of Spiennes?

Keywords: Spiennes mine (Hainaut, Belgium), jadeitite axehead, Late Neolithic, thin section, spectroradiometric analysis, sourcing.

Résumé

Il y a plus d'un siècle, Alfred Lemonnier, Directeur de carrières de craie phosphatée de la région de Mons, fit don à l'État d'une hache de jadéitite originaire de Spiennes au milieu d'une collection de « silex taillés ». À l'origine, cet artefact devait mesurer de 12 à 15 cm de long. Plusieurs scientifiques ont testé différentes manières – destructrices ou non-destructives – de déterminer cette roche verte jusqu'à retrouver l'origine à l'extrémité ultime de l'arc alpin près de Gênes (Italie), grâce au Projet JADE. Mais une nouvelle question apparaît : comment expliquer la présence d'une hache presque complète en jadéitite trouvée au milieu des exploitations de silex de Spiennes ?

***Mots-clés** : Minière de Spiennes (Hainaut, Belgique), hache en jadéitite, Néolithique récent, lame mince, analyse par spectroradiométrie, source géologique.*

Over a century ago, businessman Alfred Lemonnier donated several small but prestigious collections to the Natural History Museum of Brussels (now the Royal Belgian Institute of Natural Sciences, RBINS) while he served as Director of a phosphatic chalk quarry in the Mons area for the Solvay company (Fig. 1). An axehead made of green stone, the subject of this article is part of a collection of 'knapped flint' that the museum acquired on March 28th, 1904. This object would originally have been more than 12-15 cm long, allowing for its missing butt end.

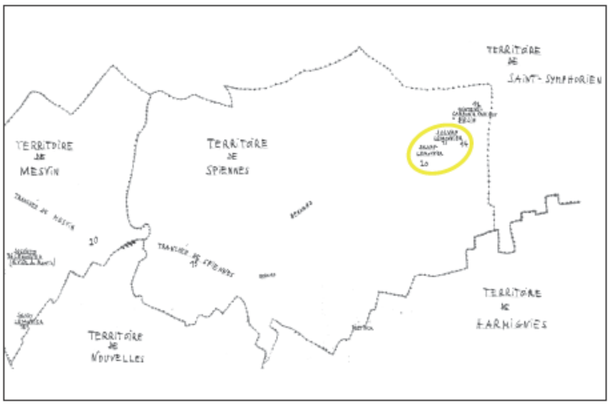


Fig. 1 – Location of the phosphatic chalk quarries managed by Alfred Lemonnier for the Solvay Company, shown against a map of the old commune of Spiennes. Archive: Jean de Heinzelin, RBINS.

Walter Campbell Smith (1963, p. 150), a member of the Department of Mineralogy in the formerly named British Museum (Natural History, BM/NH) – now The Natural History Museum – had taken a slice from the fracture surface of this axehead in order to make a petrological thin section slide (or slides), and he concluded that the type of stone was very close to other specimens that had come from archaeological sites in Brittany, France and England (Fig. 2). The remaining part of the slice that W. Campbell Smith had cut from the axehead, and kept in the BM/NH, was analysed for *Projet JADE* (Pétrequin *et al.*, 2012), using reflectance-scatter spectroradiometry. The resultant spectra were unfortunately of poor quality because of the small surface area available for measurement. Subsequently, additional spectral analyses were performed on the axehead itself, first in 2010, then in 2013 with a more powerful instrument. These analyses confirmed and clarified the original identification of the raw material (Fig. 3). It was indeed a characteristic/typical jadeitite,

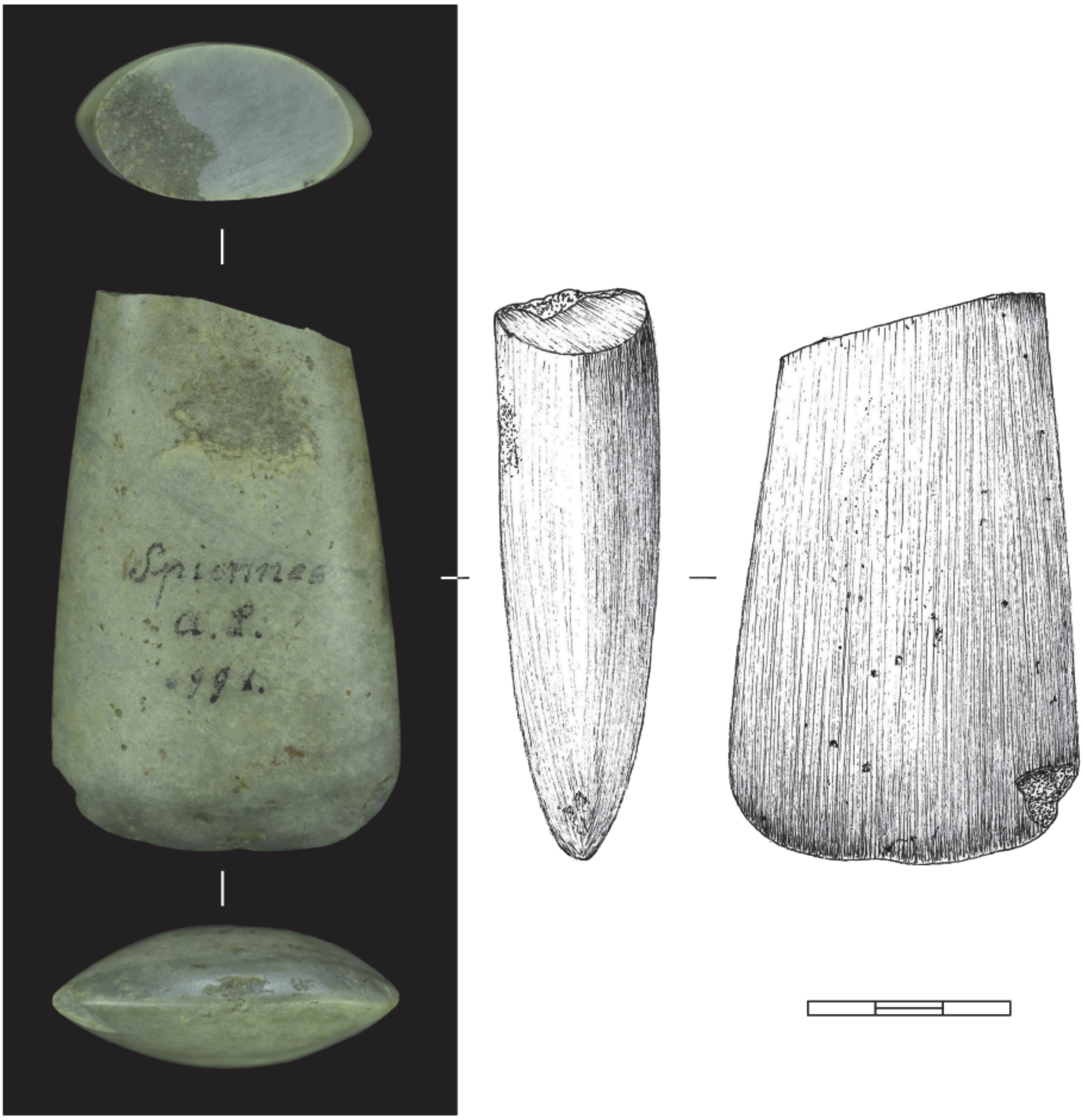


Fig. 2 – Jadeitite axehead found at Spiennes.
The photograph shows where it had been sliced for preparing one or more thin-section slides.
Drawing: Anne-Marie Wittek, ADIA/RBINS. Photographs and computer imagery: Éric Dewamme, RBINS.

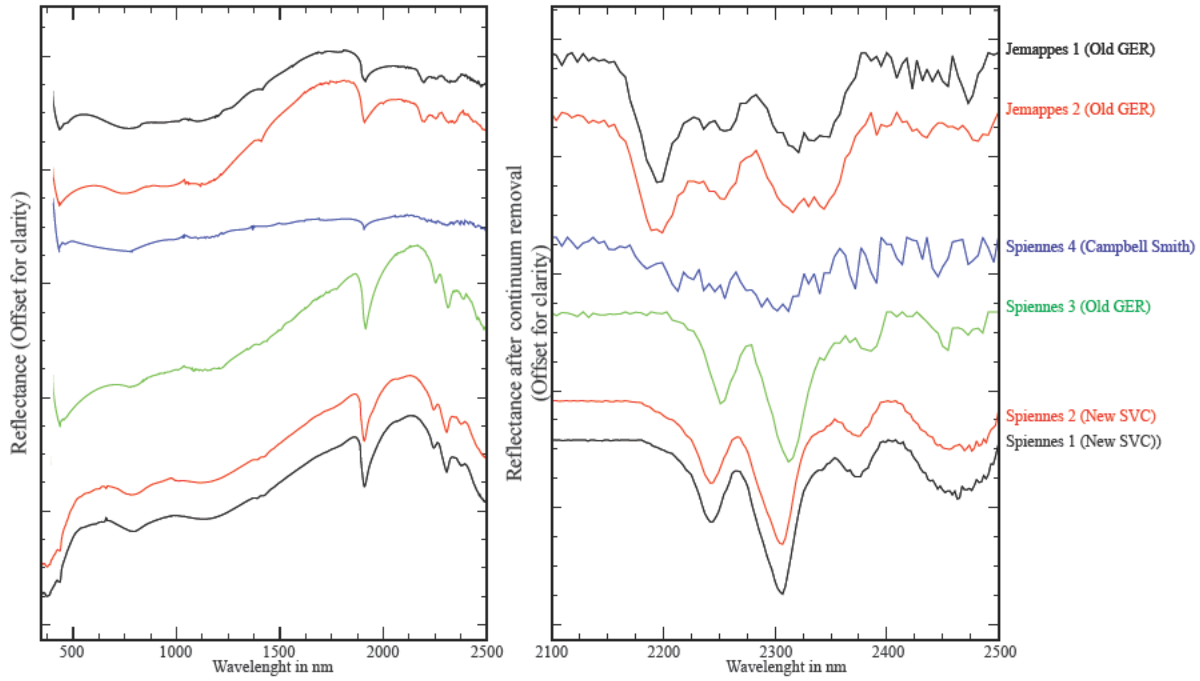
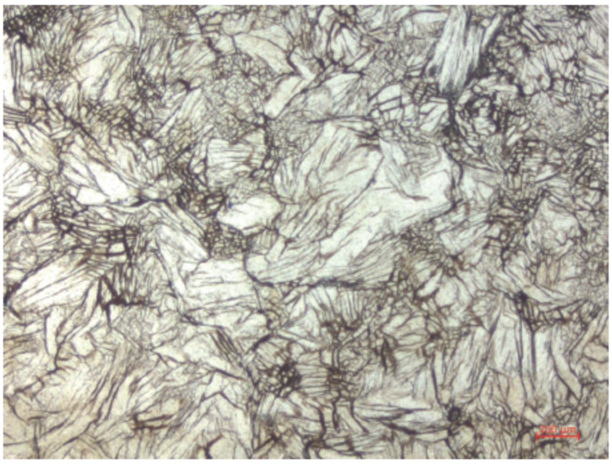


Fig. 3 – Spectra of axeheads from Jemappes and Spiennes (Mons).
Spectra Jemappes 1 (Jema_001) and Jemappes 2 (Jema_002) were determined using the old GER spectroradiometer; spectrum Spiennes 4 (Campbell Smith, Camp_008) is from the slice cut from the Spiennes axehead - note the significant noise - and spectrum Spiennes 3 (IRSN_038) was also determined using the old GER spectroradiometer. Spectra Spiennes 1 (IrScN_SVC_009) and Spiennes 2 (IrScN_SVC_008) were taken using the new SVC spectroradiometer. On the left, reflectance spectra on full-scale wavelength. Spectra taken with the old GER spectroradiometer are from 400 to 2500 nm. On the right, the same spectra between 2100 and 2500 nm, after continuum removal. Note the important absorption around 2194 nm indicating a white mica on Jemappes 1 and 2. The absorptions around 2306 (strong) and 2376 nm (medium) on the others indicate a Na-amphibole, probably glaucophane (slightly different in Jemappes 1 and 2).



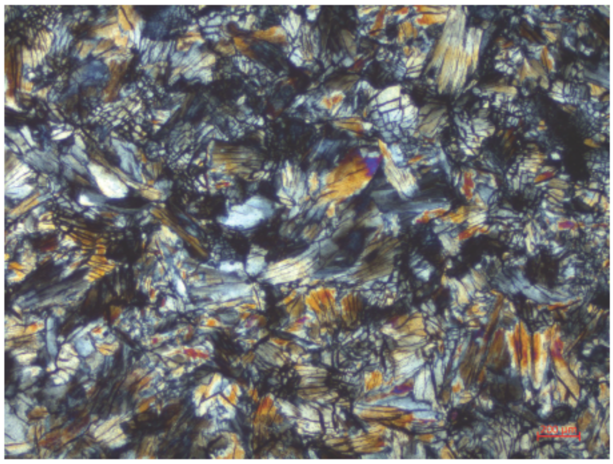


Fig. 4 – A second jadeitite axehead, found at Jemappes, was in the possession of the *Société de Recherche Préhistorique en Hainaut* (SRPH), along with a thin section. There are several indications, however, to show that this thin section actually belongs to the Spiennes axehead, rather than to the Jemappes example. On the left, the thin section is shown in natural light; on the right, in plane-polarised light. Microphotography: Éric Goemaere, GSB/RBINS.

micaceous and retromorphosed, from the blue schists facies (Fig. 3-5). The most convincing comparisons with the *Projet JADE* reference database of Alpine rocks indicate that its origin is likely to lie in the Group of Voltri, and more specifically at the west of the Beigua massif, near Genoa (Italy).

Between 1963 and when the last spectroradiometric analyses were undertaken half a century later, there have been significant shifts in attitudes towards archaeological artefacts – with a decisive move away from destructive techniques towards the use of non-destructive techniques – and also in the goals of stone axehead research. When W. Campbell Smith was writing, the goal was to characterise axeheads in the hope that this would help to locate the as-then unknown primary source areas in the Alps. Now, thanks to *Projet JADE*,

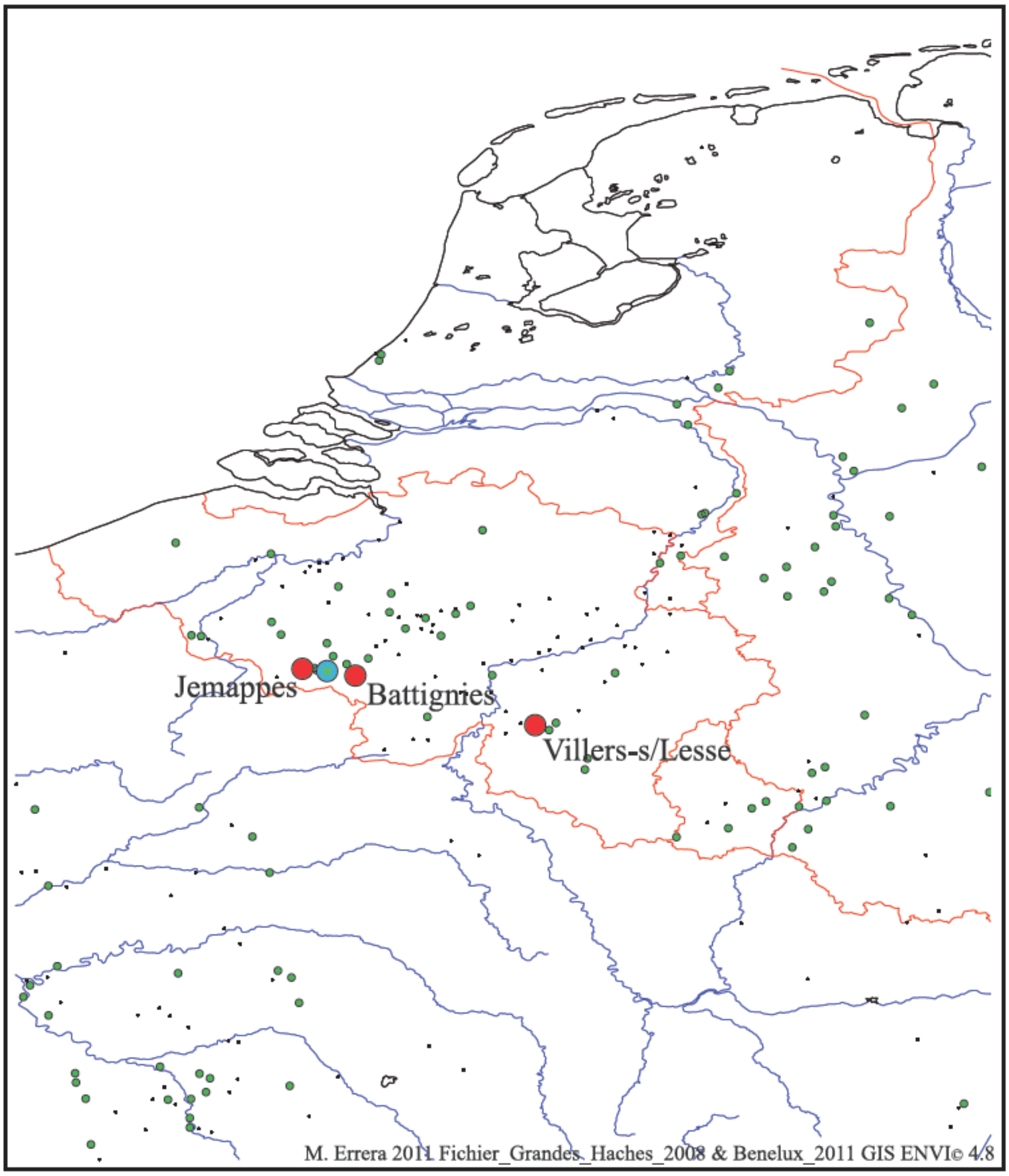


Fig. 5 – Location of the axeheads from Spiennes, Mons (blue dot) compared to others recently analysed by spectroradiometry (red dots): Jemappes (Mons), Battignies (Binche) and Villers-s/Lesse (Rochefort). The map also shows axeheads (>13.5 cm long) from the *Projet JADE* database (black dots) and, among these, ones analysed by spectroradiometry (green dots, Source GIS-JADE and ERRERA *et al.*, 2011).

the high-altitude quarries have been located and extensively studied; and with spectroradiometric analyses, it no longer makes sense to damage a museum piece in order to determine its origin; this can be achieved (at least in most cases) by simple reflection of the light on a specimen.

Now that the stone's origin has been determined, a new and fascinating question has emerged: how can the presence of a jadeitite axehead found in the middle of a production site of grey flint axeheads in Spiennes be explained?

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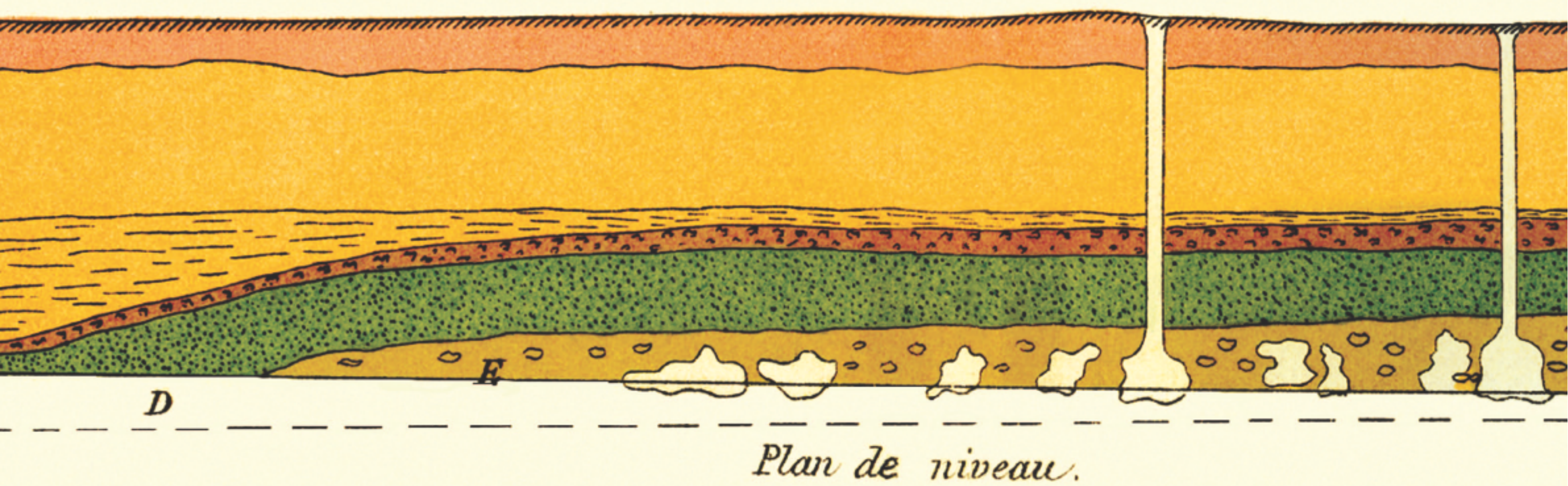
Fig. 2. Coupe de la partie orientale de la tranchée de Spiennes



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