Food practices of the first farmers of Europe: combined use-wear and microbotanical studies of early Neolithic grinding tools from the Paris basin

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Food practices of the first farmers of Europe: combined use-wear and microbotanical studies of Early Neolithic grinding tools from the Paris Basin.

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Abstract
Food practices have always been a key issue to reconstruct part of the cultural identities of past and present societies. In archaeology, the question of vegetal processing and consumption has generally been discussed through different, yet complementary lenses that include botanical remains and cooking pots. However, it has seldom been integrated in a combined approach. Our paper explores the characteristics and role of plant transformation in Early Neolithic contexts from the Paris Basin (5100-4900 BC), by combining use-wear analysis of grinding tools and the study of microbotanical remains (starch grains and phytoliths). Our integrated approach reinforces the interpretations and reduces the methodological limitations that arise when each analysis is considered separately. It also proposes a more complex vision than initially expected regarding the uses and lifecycles of grinding tools in daily plant preparation. Together with the dominant processing of cereals and legumes, tubers and rhizomes appear to have been regularly ground on querns. Different steps in plants processing are also evident, such as dehusking, heating, and sprouting. Other clues point towards the transformation of bark and ferns, known for their varied medicinal properties. These results and related methodological issues support discussions regarding the possible conservatism or innovations in vegetal food practices of Early Neolithic farmers inhabiting a region located at the most westerly point of the Linearbandkeramik expansion during the final centuries of this first wave of Neolithic dispersal throughout the European continent.

Keywords
Neolithic, Use-wear analysis, starch grains, phytoliths, food practices

Introduction

Food practices is a key issue to reconstruct part of the cultural identities of past and present societies. With the spread of the Neolithic from the Near East, agricultural systems and new food habits were introduced very rapidly by demic diffusion and colonization throughout Europe (Zohary *et al.* 2012; Rasse 2008; Salavert 2017). Among the major cultural and technical shifts that accompanied these processes, the importance of cereal consumption in the diet has been mainly explored by archaeologists through the recovery of botanical macroremains and the study of ceramic contents. However, more recent developments such as the functional analysis of grinding techniques and implements, has brought a third major contribution to discuss these evolutions. Grinding activities are still today central in daily food preparation of many populations worldwide. Highly time consuming, these activities are mostly assumed by women among other domestic tasks, and for this reason take on a very strong gendered meaning. Grinding activities also have a highly socializing value, both at the level of the familial relationships and at the village scale (e.g., Alonso Martinez 2019; Hamon and Le Gall 2013; Searcy 2011).

In north-western Europe, domestic plant and animal species and food habits were introduced as part of a global package that included a sedentary way of life organized around permanent villages composed of long houses (Hachem and Hamon 2014). At the turn of the 6th millennium BC (5200-4750 BC), Early Neolithic populations were transforming and preparing food in the frame of domestic units, which displayed strong levels of autonomy (Hamon and Hachem 2014). Our paper explores the characteristics and role of plant transformation at the turn of the 6th millennium BC among the Linear Pottery Culture (LBK) and Blicquy-Villeneuve Saint Germain (BVSG) culture from the Paris Basin (northern France and southern Belgium). Its aim is to discuss and highlight the importance of use-wear analysis of grinding tools and microbotanical remains (starch grains and phytoliths) to highlight the food practices of early farming populations. Each discipline has its own set of limitations to the type of data that can be gathered; thus, to counter this, we propose here to combine these approaches to provide a more accurate vision of vegetal food processing of the first agro-pastoral communities in north-western Europe.

Our study addresses several questions concerning the contribution of plant food in the general diet. A first set of questions concern the range of plants cultivated or gathered and their actual consumption. For example, was grinding specialized in the preparation of one or more species of cereals or was it rather a mixture of different wheats, notably einkorn (*Triticum monococcum* L.) and emmer (*Triticum turgidum* subsp. *dicoccon* [Schrank])? What was the role of legumes such as lentils (*Lens culinaris* Medik.) and peas (*Pisum sativum* L.) in the diet, and how were they prepared? Were oak acorns (*Quercus* sp.) heated or roasted before they were hypothetically peeled and consumed? Similar questions arise for edible wild plants found in Early Neolithic macrobotanical samples such as rye brome (*Bromus secalinus* L.), fat-hen (*Chenopodium album* L.), patience (*Rumex* sp.), and knotweed (*Fallopia convolvulus* L.), among others. Finally, the possibility of underground storage organs (hereafter USO), consumption, a category that includes tubers, roots, and rhizomes, needs to be addressed. Another set of questions has to do with plant processing, and the identification of different tools and techniques involved in food preparation. Can we identify different stages in the preparation, especially of cereals, prior to their grinding (dehusking, roasting, humidification, etc.)? Were grinding tools only specialized in cereal processing? And if so, at which stage of the *chaîne opératoire*? The challenge here is to identify whether grinding tools were involved more largely in food preparation and cooking, and whether they could also be used for other types of plant processing. These questions echo major deliberations at a more economic scale, especially concerning what was the contribution of vegetal food in the general diet and how was food preparation organized. Finally, it should be possible to discuss if these practices were uniform from one house to another, or from one village to another, and if a chronological evolution of food practices can be highlighted in relation to other major economic and social evolutions.

1. Archaeological context and sites

The first farming populations that colonized north-western Europe around 5300 BC, and the Paris Basin around 5100 BC, brought with them a full package of cultivated plants, breeding stocks, and new technologies including ceramics for storage and preparation, as well as grinding tools for daily food processing. The expansion of this Linear Pottery Culture originating from central Europe seems to follow a specific settlement pattern, in which loessic plateaus (Hainaut, Hesbaye) and alluvial rivers (Aisne, Oise, Seine, Yonne) were privileged. Hamlets were composed of several domestic units, including typical long tripartite houses of timber and daub and lateral detritic pits from where all the archeological material were recovered from. These hamlets were occupied for up to 200 years (Dubouloz 2012; Ilett et Hachem 2001). In very few and peculiar cases, ditched enclosures are associated with the villages (Thevenet 2016). Deposits of animal remains, ceramic and grinding tools were also identified within the domestic contexts. The organization of these hamlets seems highly dependent on the social structure (Coudart 2009; Hachem 2000) and economic pattern (Hachem and

Hamon 2014; Gomart *et al.* 2015) of LBK populations. With the emergence of the Blicquy-Villeneuve-Saint-Germain culture between 4900 and 4700 BC, a strong regionalization process emerged, together with the colonization of new territories, especially to the west and south-west. While traditions rapidly evolved under different influences especially from the Mediterranean sphere, technical innovations were also introduced, such as the production of schist bracelets, and a reorganization of exchange networks (Manen and Hamon 2018). Between 4700 and 4350 BC, less structured occupations -known from pits and light houses- as well as new technical traditions emerged with the Cerny culture. In this context, food practices, production, and consumption, are an important issue to explore.

In the Paris Basin, basic knowledge of the plants processed and consumed in the Early Neolithic is based on the rather limited archaeobotanical record from about fifty sites spread from the Aisne Valley in the south to Hesbaye in the northwest (e.g., Bakels 1999; Diestch-Sellami 2004; Salavert 2010; Berrio 2011; Hamon *et al.* 2019). The most solid data concerns cultivated plants, mainly cereals. Indeed, for pulses – peas (*Pisum sativum*) and lentils (*Lens culinaris*) – as well as for oil/textile plants such as flax (*Linum usitatissimum*), few elements are available to provide clues to the ways in which these were processed and prepared before consumption. With regard to cereals, hulled wheat such as einkorn and emmer are dominant in the Early Neolithic (LBK/BVSG). Nevertheless, naked cereals such as wheat (*T. turgidum/durum/aestivum*) and barley (*Hordeum vulgare* subsp. *nudum*) appear more significantly in the BVSG perhaps under the influence of Cardial Neolithic populations from the northwestern Mediterranean basin (Bakels 2009; Gassin *et al.* 2010; Peña-Chocarro *et al.* 2013; Antolín and Buxó 2012). The morphological differences between naked and hulled cereals have certainly influenced several stages of the *chaîne opératoire* of plant processing. For example, in the dehusking stage, where the grains are released from their husks, hulled cereals require a higher investment because of the adhesion of the chaff (glume, inner glumes) to the caryopsis (seed). For naked cereals, the caryopses are released from their chaff after threshing (Cappers and Neef 2012).

Furthermore, the presence or absence of certain elements (rachises, spikelet bases, glumes) of cereal chaff in archaeobotanical assemblages can provide information on the scale of cereal processing. For example, in central Belgium, spikelet bases and glumes account for nearly 22% of cereal residues whereas rachises are rare (0.6%), similarly to most of the LBK sites in central Europe (Bogaard and Jones 2007; Salavert 2010). The rachis, which corresponds to the base of the cereal inflorescence, comes from the first stages of processing just after threshing. The rarity of rachises in Early Neolithic archaeobotanical assemblages indicates that this processing stage probably took place outside the domestic space (Bogaard and Jones 2007). Thus, residues from these early processing stages, such as rachises, stems, and certain weeds do not enter the archaeobotanical record at sites. The plant assemblages found in the refuse pits are therefore proof of a second stage of transformation (post-storage dehusking) carried out on a domestic scale, perhaps as and when needed. At Colombelles "Le Lazzaro" (Calvados, France), a large BVSG refuse pit mainly delivered the remains of hulled cereal chaff as well as a few grains and rachises (Dietsch-Sellami 2014). The rarity of rachises supports the idea that the post-storage processing of this type of cereal may have been carried out inside or near the houses using grinding tools for example.

Data on the gathering, preparation, and consumption of wild plants through archaeobotany are also subject to many constraints, such as the preservation conditions at the site (dry *versus* waterlogged), conservation limits of certain plant organs (USOs, leaves, inflorescences), or the fact that these edible plants can also be weeds on cereals plots (Colledge and Conolly 2014; Berihuete-Azorín 2016). Nevertheless, while the role of gathering is often estimated as secondary in the plant economy of the farming societies, the consumption of wild indigenous plants is recognized in the Paris Basin (Diestch-Sellami 2007). One of the most common seeds in the Early Neolithic is the fat-hen (*Chenopodium album*), the consumption of which is attested at LBK sites (Mueller-Bienek *et al.* 2019).

Large quantities of grinding tools are present in the lateral refuse pits flanking the tripartite houses. They are preferably rejected next to the probable main access (doors and windows) (Hamon 2006). Grinding tools are generally made from local to regional well-cemented quartzitic sandstones from Tertiary levels of the Paris Basin (Hamon and Fronteau 2018; Hamon and Goemaere 2007) and more rarely on granites from the margins of the Armorican Massif. They display several typological characteristics. Several sizes of querns and grinders coexist at these settlements and appear complementary in function. Use-

wear analysis? indicate that approximately 70% were used for the processing of cereals, either for dehusking, or for the grinding of clean grains (Hamon 2008, 2014). Deliberate practices of breakage have been observed, with quite systematic schemas of fracturing, a practice that seems widespread throughout the LBK and that may reflect some ritual linked to the life and death of the users of these tools (Hamon 2006; Verbaas and Van Gijn 2007). One of the particularities of this region is the existence of thirteen grinding tool hoards more or less found in direct connection with the domestic units (Hamon 2008a,b). These structures contain complete grinding systems deposited in storage position, in piles, or circles, with their active surface facing downwards. Paired querns and grinders are deposited together with the hammerstones used for their regular re-sharpening. The tools deposited generally show intense and complex cycles of use. This unique phenomenon at the scale of the LBK, and more broadly at the scale of the neolithization of central and western Europe, definitely leads us to question the symbolic value of these practices. Are they related to foundation or abandonment rituals? Do they constitute the storage areas of craftsmen? Or is the practice of burying food implements tied to agricultural rituals on the western margin of the LBK expansion?
Thus, the contribution of the functional study of grinding tools, based on use-wear and micro-residue analysis, is essential to better understand the diversity of practices related to the consumption of plants, cultivated or wild, in the Early Neolithic period in the Paris Basin.

The majority of the tools analyzed come from settlement sites, and from the lateral refuse pits that contain all types of archaeological material related to the LBK and BVSG long houses. Two specific contexts have also been taken into account. Several sites offer special contexts consisting of hoards or paired quern and grinder deposits in the Hainaut region (Hamon 2008), as well as at the sites of Loison (Praud *et al.* 2018), Ath (fosse 12), Berry-au-Bac (Hamon 2006) and Saint-Denis (Samzun and Hamon 2004). Another particular context concerns the enclosure of Menneville (Thevenet 2016). In this LBK enclosure located in the Aisne Valley, several deposits of animals together with atypical human burials have been discovered in link with sacrificial practices (Thevenet *et al.* in prep.). The fill of the ditch offered an important quantity of broken grinding tools, suggesting sacrificial practices of the tools that have not been observed in typical domestic context. Among these afore-mentioned sites, a sample of nine sites have been selected to conduct a functional analysis of grinding tools, associating use-wear and residue analysis (fig. 1). Three are dated to the LBK culture, five to the BVSG culture and one to the Cerny culture, in order to cover all the sequence of the Early Neolithic and beginning of the Middle Neolithic in the Paris Basin. They cover the entire geological Paris Basin area, from Hesbaye (Belgium) to the east to the Caen plain (France) to the west.

2. Material and methods

Functional analysis of grinding tools has been subject to many improvements and debates since the first use-wear analysis was conducted in the 1980's (Adams 1989). In the 1990's, R. Fullagar and colleagues (1997) set up the principles of combining methodologies to enlighten our understanding on the function of grinding tools, based on use-wear and microbotanical residues analysis. In 2002, H. Procopiou and colleagues (2002) proposed the first highly integrative and combined approach concerning the function of grinding tools. Their study included petrography, use-wear, phytoliths, and chemical analysis. Scholars subsequently worked on the creation of a solid reference collection and explored the limitations of each method separately, which led to the significant improvement of the characterization of how macrolithic tools work and of their function(s). Today, the combination of use-wear and residue analysis appears more frequently in the literature, and has been tested with success in different contexts, from Australian hunter-gatherers (Hayes *et al.* 2018) to the first agricultural populations of the Near East (Portillo *et al.* 2013), north-western Europe (Hamon *et al.* 2011), and China (Liu *et al.* 2014).

2.1 Use-wear analysis

2.2.1 General principle

As part of a technological approach, use-wear analysis aims at reconstructing the production and function of archaeological tools through their shaping and use traces, by analogy to natural, taphonomical, experimental, and ethnographical reference collections, for which uses are known.
Use-wear analysis applied to "groundstone" and "macrolithic" tools emerged significantly in the 1980's with the first works of J. Adams (1989). Since the end of the 1990's, reference collections were built to establish a comparative framework for different raw materials (sandstones, granites, basalts, etc.), grinding and pounding systems (back-and-forth, circular or vertical movements) as well as the transformed matter (cereals, legumes, plants, colorings, grog, bone, etc.) (e.g., Dubreuil 2004; Hamon 2008; Risch 2002; Hayes *et al.* 2017). In the meantime, the scales and techniques of microscopic observations were progressively combined, and quantification analysis based on rugosimetry, confocal microscopy, as well as combined 3D and GIS, allowed a gain in accuracy (Boffill 2013, Caricola *et al.* 2018, Zupancich *et al.* 2019).
As a matter of fact, use-wear analysis has a great advantage in that it is capable to explore all the range of possible functions, functioning, and transformed matter using a single method. It offers a unique opportunity to quantitatively analyze important and representative samples of tools with one single method of functional analysis. Such analyses make sense only when they are applied to a large series of tools, in order to avoid bias related to, for example, raw material or intensity of use variability. Use-wear analysis is a powerful means to approach detailed technological features including kinematic, (gesture, movement, manipulation mode), and type of action of a tool. Likewise, several levels of information can be recognized to characterize not only the nature of the transformed matter, but also its texture, quality, state, stages of preparation, etc. All these criteria constitute technical choices and habits that define technical traditions, at the base of socio-economic models at high-resolution.

Thanks to different research, the use-wear characteristics of cereals, legumes, USOs, grasses, seeds and nuts are now well studied, identified, and recognizable. The main characteristics of the use-wear resulting from the processing of these different plants can be summarized as follow at the macro and micro scales (after Adams 1989, Dubreuil 2004, Hamon 2006, Boffill *et al.* 2013, Hayes *et al.* 2018, Cristiani *et al.* 2020). As a matter of fact, the processing of each great category of plant generates distinctive use-wear signature, at least from an experimental point of view (fig. 2).
Cereal grinding is characterized by a strong surface levelling, a covering smoothing of the areas in relief and general grain rounding; the corresponding micropitted micropolish displays a certain roughness, with reticular morphology, a dull to moderate brightness and fine striations. A different pattern characterizes dehusking operations, more impacted by the silica component of the cereal glumes (phytoliths): the smoothing is much less developed, the roughness of the surface higher, the micropolish highly micropitted. The pretreatment of cereals, by roasting or soaking, creates specific use-wear traces, especially in the second case as water absorbed by the grains functions as a lubricant in the mechanical process of grinding. The presence of water slows down the levelling of the surface, but on the contrary accelerates the rounding of the grains.
Legume and acorn processing generates a strong levelling in plateau, a smoothing on the higher areas, and a dull aspect. The hardness of the legumes also generates microchipping, and in some cases microstriations.
Due to the presence of natural lubricants, greasy nuts processing generates a protective film, which slows the mechanical levelling of the surface but accelerates the development of smoothing and of grain rounding. This greasy component also generates strong superficial brightness.
Hard seed grinding shows diverse intensity of surface levelling as well as grain rounding, while the micropolish appears reticular and relatively bright, with again diverse coverage and development depending on the type of seeds processed.
Grass processing generally leaves very ephemeral traces on the surfaces and are difficult to identify: they rarely impact the microtopography or the surface of the grains. As for USOs, this category of plant organs has generally been neglected from experimental tests, and their specific use-wear signature is largely to be defined.

2.2.2 Sampling strategies and taphonomic preservation

Use-wear analysis was conducted at low magnification with a stereomicroscope Nikon SMZ800 and at high power with a metallographic microscope Olympus BXFM. Our reference collection consists of more than 150 experiments, taking into account numerous tests that include grinding, abrading, and softening. Among these tools, lower and upper tools were employed for the grinding and dehusking of cereals, legumes, and other plants, mineral matter such as ochre, clay, and temper (flint, grog, etc.), and animal matter such as bone for temper, dry and fresh meat, etc. (Hamon 2008; Hamon and Plisson 2009; Hamon 2014).

After a comprehensive review of the typological characteristics of a complete macrolithic tool assemblage, it is then possible to sample the tools for use-wear analysis, in accordance with their chronological, contextual, and typological representativity within a site or a chrono-cultural context. For the Early Neolithic of north-western Europe, beyond domestic lateral refuse pits, particular contexts needed special attention and strategies of analysis, notably quern hoards, funerary deposits, silos, fireplaces, etc. The disposition of the tools within the structure as well as their possible secondary position are important factors to be considered to ensure a solid understanding of what is being analyzed.

Taking all these prerequisites into account, 1710 complete macrolithic tools were selected in order to correlate use-wear analysis with typologically well-defined and well-contextualized tools. Among them, 269 grinding tools were analyzed, including 50 querns, 124 grinders, 74 fragmented grinding tools, 10 grinding slabs, and 11 small circular grinders (Hamon 2014). These tools were selected according to a series of intrinsic criteria that constitutes prerequisites for use-wear analysis: 1) low fragmentation and highly informative on a typological level, 2) well-cemented raw materials and a good state of preservation of the surfaces, 3) low degree of taphonomic alterations related to heating, freezing, water circulation or chemical deposits (calcite, etc.) that may alter the preservation of the traces, and 4) good conditions of washing and storage of the tools (with or without a brush, detergent, diluted acid, etc.) that may otherwise alter or damage the surfaces. Among these 269 tools, a series of 32 implements were considered suitable for further microbotanical residues analysis, including 13 querns, 18 grinders, and 1 undetermined grinding tool. The selection of grinding tools for residues analysis was guided by several criteria we considered as prerequisites to limit all possible biases: 1) complete tools (which are finally rare), 2) with typological meaning, 3) possibly paired set composed of querns and grinders, 4) low degree of alteration of the active surface, 5) possibility to get comparative sediments from the pit, and 6) the possibility to wrap the tools following their excavation to limit external contamination. This explains that the number of tools selected for residues analysis was reduced by comparison to the initial amount of grinding tools analyzed.

2.2 Starch Grains

2.2.1 General principle

Starch grains have been successfully extracted from tools (Cagnato and Ponce 2017), ceramic vessels (Wang *et al.* 2016), organic vessels (Duncan *et al.* 2009), dental calculus (Henry *et al.* 2011), coprolites (Horrocks 2006), intestinal remains (Cagnato *et al.*, *in press a*), and sediments (Therin *et al.* 1999), and its presence has played an important role in answering questions related to ancient diets, past environments, domestication, food processing, patterns of land use, and tool use (Cristiani *et al.* 2016; Crowther 2012; Henry *et al.* 2014; Horrocks *et al.* 2008; Liu *et al.* 2014; Piperno and Holst 1998; Yang *et al.* 2013). Very few starch analyses have been carried out in Temperate Europe. With regards to the Neolithic period in the Paris Basin, one previous study, which considered nine grinding stones, recovered starch grains on six of these, revealing the presence of wheat, barley, oats, acorns, and peas at the Belgian LBK site of Remicourt "En Bia Flo II" (Chevalier and Bosquet 2017).

Starch grains are energy storage units of plants, composed of two different glucose chains (amylose and amylopectin), and are tiny, ranging from 1 to 100 μm (1 μm = 0.001 mm). They are synthesized in plastids during photosynthesis and then primarily stored in underground storage organs, seeds, and fruits. Starch grains, like other macro (seeds, fruits, inflorescence elements)- and microbotanical (pollen, phytoliths) remains, display a range of diagnostic characteristics that can in some cases permit their taxonomic identification. Features include the size and shape of the starch grain, as well as the location of the hilum, presence of lamellae, fissures, and the morphology of the extinction cross, also known as a Maltese cross, a feature visible only when the starch grains are viewed under cross-polarized light (Gott *et al.* 2006). It must be noted however that this methodology does have limitations, notably the fact that not all grains are diagnostic, and that in some cases, there is overlap in the morphology of species (see Copeland and Hardy 2018; Gott 2006). However, this methodology is a good indicator for the presence of starch-rich plants, which is especially true of cereals, pulses (legumes), and underground storage organs. The latter are particularly difficult to recover in the archaeobotanical record, and therefore starch grain analysis is essential to document their presence in the past. Starch grain analysis is not typically a good indicator of oily plants, which in the case of the Paris Basin would include flax (*Linum usitatissimum* L.), and hazelnuts (*Corylus avellana* L.). Moreover, not all plants produce diagnostic starch grains, which is the case of the opium poppy (*Papaver somniferum* L.) found at Early Neolithic sites in Europe (Bakels 1992; Salavert 2010, 2011).

2.2.2 Taphonomic questions and preservation

Although starch grains are fragile in that they will deteriorate easily if not protected, and readily decomposed by chemical and biological processes as well as affected by the presence of bacteria and soil-microorganisms (Kubiak-Martens 2016; Langejans 2010), they have been found in numerous contexts, even where conservation seems improbable (such as in carbonized samples), but also in very old contexts (i.e., Middle Paleolithic) (Mercader 2009). This has led some scholars to question the antiquity of these microscopic elements, citing contamination from modern sources as a possible cause (Crowther *et al.* 2014; Loy and Barton 2006; Mercader *et al.* 2018). While the exact mechanisms of this long-term survival of starch are still relatively misunderstood, scholars have proposed that environments with low water availability, relatively low temperatures and neutral pH could favor its preservation (Copeland and Hardy 2018; see Mercader *et al.* 2018 for a detailed review).
Starch grains are affected by external processes, such as cooking, grinding, but also more natural ones involving the properties of the soil as well as the presence of enzymes and fungi (see Haslam 2004).
Cooking foods rich in starch is especially necessary for breaking down complex starch polysaccharides into more easily digestible sugars and in many cases to remove toxins (Crowther 2012). However, this not only alters the physical and compositional characteristics of starch grains but can also alter or destroy the morphological and optical properties that allow analysts to identify them. In fact, two of the most critical variables that affect a starch grain's response during cooking are temperature and moisture (Crowther 2012). The effects of cooking (heat) on starch grain morphology has been demonstrated by a number of experimental studies (Babot 2003; Chantran and Cagnato *accepted*; Henry *et al.* 2009; Pagán Jiménez *et al.* 2017). Similarly, grinding and pounding affect starch grains, and experimental studies have sought to study the stigmata left behind by such processes (Babot 2003; Cagnato *et. al, in press b*; Li *et al.* 2020; Ma *et al.* 2019; Mickleburgh and Pagán-Jiménez 2012).

2.2.3 Sampling treatment

Only unwashed artifacts were selected for this study. The starch grain and phytolith (see 2.3 section) samples were taken from the entire active surfaces of the grinding tools prior to the use-wear analysis. To collect the starch grain and phytolith residues, the artifact was gently scrubbed using a new, clean toothbrush and distilled water. The sediment and water (sample) collected in this manner was transferred to a clean, plastic container, sealed with a lid, and labeled. Each sample was then halved into another clean container for phytolith analysis. Comparative sediment samples, obtained for 16 out of the 32 artifacts selected, were also taken from the excavation units where the grinding stones were recovered, to estimate the level of possible contamination as a result of plant remains from nearby sediments. This has become a more common practice when studying archaeological residue analysis (see for example Barton *et al.* 1998; Piperno *et al.* 2000).
The laboratory methods followed those outlined by Cagnato and Ponce (2017), which includes the use of different chemicals (EDTA, hydrogen peroxide, sodium polytungstate) to remove organic components and separate the starch grains from the sediment. Using a reference collection, the starches were identified. It should be noted that a starch grain reference collection for the Paris Basin did not exist, and therefore it had to be created. The plants considered include all the cereals, legumes, and wild

plants that have been so far reported from the archaeobotanical record of the region (Bakels 1984, 1992, 1999, 2010; Chevalier and Bosquet 2017; Jadin and Heim 2003; Diestch-Sellami 1997; Salavert 2011; Saqalli *et al.* 2014). However, other plants, not reported from this period were also included, namely USOs. A total of nearly 99 taxa in 35 families of domesticated and wild plants were tested, however, not all contained diagnostic starch grains (Cagnato *et al*, *in review*).
Only starch grains that could be fully rotated were considered in this analysis. Starch grains were observed and photographed at 600× in both cross-polarized and plane polarized light using the program NIS-Elements. Starch grains were identified by the presence of the distinct extinction cross, the presence or absence of features such as the lamellae and fissures, and whether the hilum was open or closed, among other things. The terminology used in the study follows that established by the International Code for Starch Nomenclature (ICSN 2011). The same methodology was utilized to process the comparative samples.

2.3 Phytoliths and Non-Pollen Palynomorphs (NPP)

2.3.1 General principle

During the growth cycle of most plants, water soluble soil silicates are absorbed by the roots. During evapotranspiration, silicates precipitate: the phenomenon occurs in the epidermal tissues of leaves, stems, and inflorescences of Poaceae (monocotyledons), while in dicotyledons it occurs in the tissues of needles and leaves, as well as in the wood and bark. Phytoliths thus constitute solid deposits in extra and intracellular spaces.
The morphology of these mineral micro-residues is comparable to that of the cell in which - or around which - they precipitate, so they are of great taxonomic value. They are released when the plant tissue that contains them decomposes and eventually become micro-fossils of this plant. Their chemical composition enables them to resist biochemical attacks relatively well and they are an integral part of archaeobotanical studies with the ability to provide information in contexts where seeds, pollen grains, and charcoals are poorly or not preserved.
Phytoliths are classified into different morphotypes and it is difficult to identify precisely an isolated element because of redundancy (the same plant can produce several different morphotypes) and multiplicity (the same morphotype appears in many plants). There is therefore no simple relationship between taxa and morphotypes. However, many of the morphotypes identified can be related to the two main groups of plants: monocotyledons and dicotyledons. The taxonomic classification currently proposed distinguishes between Poaceae, woody dicotyledons, and some specific families, i.e., monocotyledons other than Poaceae and non-woody dicotyledons (Novello 2012: 56-69; Garnier 2013: 112-131).

Phytoliths identification

Among the different forms of phytoliths, "short cells" make it possible to identify the Pooideae subfamily (wheat, barley, oat) and that of the Panicoidae (millet). The long cells make it possible to discriminate between stems and leaves and inflorescences. Morphometric characteristics of the connecting dendritic cells from the grain envelopes (glumes and inner glumes) have been used to identify the genus and sometimes even the species (Madella *et al.* 2005; Rosen 1992). Long dendritic cells of the glumes and inner glumes, more frequent than silicified epidermal tissues because they are better preserved, are still under study as morphometric data vary from one species to another (Ball *et al.* 1999; Berlin *et al.* 2003; Portillo *et al.* 2006, 2009). The naming used is consistent with that of the International Code for Phytolith Nomenclature (ICPN) 1.0 (Madella *et al.*, 2005) and 2.0 (Neumann *et al.* 2019).

Poaceae subfamily Phytoliths
In a first classification, Twiss *et al.* (1969: 109-115) differentiate between "Grass Short Cells Phytoliths" (GSCP) and "Elongate" (long cell, ICPN 1.0), but only the short cells are morphologically different within the Poaceae subfamilies. Three classes of GSCP are therefore proposed: "bilobate" and "cross" for Panicoideae, "saddle" for Chloridoideae, "rondel", "ovate", and "rectangle" for Pooideae (or

Festucoideae) to which the cereals belong (Brown 1984: 345-368; Mulholland and Rapp 1992: 65-89; Fredlund and Tieszen 1994: 321-335; Fahmy 2008: 1-23).

Phytoliths in Poaceae inflorescences

The spikelets of Poaceae inflorescences, and thus of cereals, are attached to the ears by their rachis; at their base two thick envelopes - the glumes - protect the caryopses, each of which is surrounded by two inner glumes (lemma and palea). Although a general description can be attributed to them, these elements differ from one envelope to another and for the same envelope from its base to its end.

Only dendritic cells (dendritic phytoliths), articulated silicified epidermal tissues, and papillate (papillae, ICPN 1.0) are specific to Poaceae inflorescences, the latter representing the inner surface of cone-shaped phytoliths or epidermal cell hairs (Fig. 7a, b & c). The large dendritic phytoliths are thin and fragile pieces of tissue with articulated cells. The contact between the cells consists of adjacent lobes or "waves" (Rosen 1992: 129-147).

The key to determining cereal phytoliths has been the subject of long research, the steps which are not discussed here. Rosen (1992: 129-142) has conducted comparative studies on the multicellular structures of cereals in existing plants and in archaeological sediments. She studied the height, width, and shape of the 'waves' and the diameter and number of perforations of the papillate (papillae, ICPN, 1.0) and showed that they are characteristic of the species.

According to Ball *et al*. (Ball *et al*.1999: 1615-1623) a classification based on these criteria is valid, but a taxonomic classification requires more criteria.

In order to differentiate between taxa which produce the same morphotypes, morphometric studies can improve taxonomic resolution.

The International Committee for Phytoliths Morphometrics (ICPM) was created on the initiative of the International Phytolith Society (IPS) in order to define methodological standards, these continue to be refined (Ball *et al*. 2016: 106-111; Portillo et al. 2020: 246-256).

Regarding cereals, computer-assisted imaging and statistical analyses were used by Ball (Ball *et al.* 1999: 1615-1623; Ball *et al.* 2009: 505-512) to develop a classification key to identify populations of phytoliths produced by the inflorescence bracts of wheat and barley species.

Such a classification is a useful tool for archaeobotanists. Species analyzed were selected for their historical, economic, agricultural, and archaeological importance and include *Triticum monoccocum* L. (einkorn), *T. dicoccon* Schrank. (emmer), *T. dicoccoides* Körn., *T. aestivum* L. (bread wheat), *Hordeum vulgare* L. (two-row and six-row barley), and a wild relative of cultivated barley, *H. spontaneum* C. Koch.

Other elements identified

Non-pollen palynomorphs (or NPPs) are microscopic organisms of 10-250 μm with a characteristic morphology resistant to decomposition processes and to standard laboratory treatments (Miola 2012). They are palaeoecological and palaeoenvironmental indicators (Geel van 2002). NPPs are particularly numerous and come in a variety of shapes. In this study they include spores of fungi and Pteridophytes, sap-conducting vessels, fibers, and leaf epidermis but also animal micro-fossils such as sponge spicules.

2.3.2 Sampling treatment and taphonomic preservation

The same method and precautions were applied during the recovery of adhering starch grain and phytolith residues on the grinding tool's active surfaces (see section 2.2.3). For phytolith analysis, the sample is then separated by centrifugation and treated according to the physico-chemical protocol established for phytolith extraction (Piperno 2006). The treatment is then repeated on the comparative sediment samples to verify that the micro-residues identified on the active face are related to the work done on the grindstone. For a few samples, the quantity of sediment sampled on the active surface was unfortunately not sufficient enough to proceed to both starch grain and phytolith analysis (tab. 1). It should be noted that as the NPPs were observed in the phytolith slides and that no special preparation was made to recover them, this list may not be exhaustive.

Not all the phytoliths concerned are present in the sediments sampled, some of the more fragile ones are not preserved and their absolute frequencies do not allow for statistical studies. However, the reference collections and the characteristics of multicellular silicified structures and "papillae" allow reliable determinations. The different stages of cereal processing aim to separate the distinct parts of the plant from the seeds to be ground. Here, we consider the processes of husking and grinding, which take place after harvesting and threshing. Two types of cereals can be represented: hulled grain cereals or caryopses and naked grain cereals. In the first case, the caryopses are enveloped by protective glumes and inner glumes, their removal on the grinding stones leaves analyzable residues in the form of articulated silicified epidermal tissues. These allow the identification of the plant and their frequencies can attest to this process. It should be noted that the shape of the silicified structures can be related to the mode of threshing. In the case of free-threshing cereals, husking is not required as the envelopes are released during threshing.
With regards to husking, the spikelets can be humidified, which makes it then possible to observe certain animal or vegetal micro-fossils such as sponge spicules and diatoms. The winnowing carried out at the end of husking results in the elimination of the glumes and inner glumes, some fragments may remain and be present on the tools after the grinding operation; if this is the case their frequency will be lower. However, there are many uses for grinding tools and various phytoliths may be present, providing information on the function of the tools involved and the elements worked on.

3. Results

3.1 Technological and use-wear analysis of grinding tools

Use-wear analysis was conducted in order to answer several questions. Were all the grinding tools used for the processing of cereals, and what was the importance of cereals in the diet of early farming populations? What other transformed matters were processed in relation to food preparation? Were these grinding tools uniform in their function and what was their exact role in the processing of plant foods? Finally, what was the role of food processing in the social organization of these populations?

Technological and use-wear analysis of 248 grinding tools demonstrate that several grinding systems coexisted with different functions (Hamon 2014). As a matter of fact, the morphology and dimensions of grinders suggest different manipulation systems, with mostly a back-and-forth motion, and secondly a more diversified linear, circular, or multidirectional grinding gesture. This has implications in the way the matters are transformed and on the regularity of the final products obtained. A more constrained gesture would imply a higher degree of homogeneity of the final products, while circular motion appears more suitable to reduce heterogeneous fractions of matter. Consequently, one could suggest that back-and-forth motions are more related to a standardized gesture of daily cereal grinding, while other motions could be related to other functions.

Of the total assemblage, use-wear analysis shows that 65% of the grinding tools studied were mainly or exclusively involved in cereal processing. Although high, such a percentage could appear quite low considering the widespread notion that paired querns and grinders were related to cereal transformation among early farming populations. Besides, this value could hide more complex and diversified stages of plant transformation. We are faced here with a limitation of use-wear analysis, which generally overestimates the functions identified through well-developed use-wear by comparison to more discrete and less visible activities. In this sense, cereals are more likely to produce well-developed use-wear traces. Moreover, the daily processing of cereals over several hours implies automatically a higher rate of trace development. Other plants, such as legumes or USOs, produce characteristic use-wear traces, highly recognizable, and distinct from those seen in cereal processing (Dubreuil 2004; Bello-Alonso *et al.* 2020; Revedin *et al.* 2015). However, none have been recognized on our set of grinding tools through use-wear analysis. Along the same vein, a wide range of herbs have very low abrasive impact on the surfaces and may have been underestimated, grass grinding has been rather well-identified on half of the small circular grinders, but recognized only on 2% of the querns and grinders. This statement supports our previous suggestions regarding the adaptation of some gestures to the transformation of specific transformed matters. It also suggests the low degree of specialization of grass processing tools by comparison to implements dedicated to cereal transformation. In summary, cereal grinding was a dominant activity among early farming populations in the region, though the question of their specialization remains an open question.

The question of the primary *versus* secondary use of grinding tools is also an important, but challenging issue in LBK and BVSG contexts. The refuse position of the tools as well as their high rate of (in-) voluntary fragmentation leads us to question the possibility of reuse. In this respect, the use of 14% of the grinding tools for the processing of mineral matter and of 4,8 % for animal matter is intriguing. The use or reuse of grinding tools for temper production is a possibility and could fit with the existence of bone as well as grog and mineral temper in Early Neolithic ceramics of the Paris Basin. However, the processing of hard animal matter could also relate to food production, as marrow and broken bones are often used in the elaboration of broth. Regarding mineral matter, 3,6 % are used for the processing of soft mineral matters, and 1,2 % of the tools are related to the processing of dyes, especially red in color, used and processed in varying quantities throughout the LBK and BVSG.

Concurrently, several size categories appear among the tools, and at least two seem to coexist at the sites (Hamon 2006). Use-wear analysis suggested that these two size ranges were complementary in function for the processing of cereals. Based on a specific experimental reference collection (Hamon 2006, Cagnato *et al.* in press b), use-wear analysis suggests that smaller grinders used for cereal processing were involved in dehusking operations while larger ones were preferably used for grinding. The use of smaller tools could be linked to their weight: the pressure of heavier tools would open the grains rather than dehusk them. Besides, a circular gesture would ensure a better “rolling” of the grains under the tool, suitable for dehusking operations. In any case, this suggests the existence of complementary sets of grinding tools within domestic units. With regards to the processing of cereals, it seems that a certain degree of specialization of grinding tools existed on the basis of their shape and size and was oriented towards different stages of cereal preparation. This higher rate of grinding tool specialization involved in cereal processing can be placed alongside the existence of a rather complex *chaîne opératoire* for the treatment and processing of cereals among the first agricultural populations.

Six of the 32 tools chosen for combined use-wear and residues analysis were finally deemed impossible to study due to alteration processes of the raw material (tab. 1). As a matter of fact, cereal grinding was identified as the predominant use of most of the grinding tools used in a back-and-forth motion. In seven cases, the processing of wet matter was recognized, suggesting the humidification of cereal grains prior to their grinding. For a few samples, the processing of partially dehusked cereals was proposed, while on others the grinding of well-cleaned grains occurred (e.g., Loison-sous-Lens). Several samples display signs of intense stone against stone contact, in relation to the grinder/quern abrasion. The two grinding stones from the Cerny site of Choisy, used in a rather circular motion offer a different use-wear pattern, suggesting the processing of plants other than cereals. Besides, it is important to underline the relative homogeneity of the use-wear traces and function of the tools found in hoards at Berry-au-Bac and Ath, as well as to a lesser extent the use-wear patterns of the complete grinding tools deposited at Loison-sous-Lens (fig. 3 and 4).

To sum up, use-wear analysis is a powerful means to highlight the range of grinding tools used within a site and a given cultural-context. For the Early Neolithic of north-western Europe, use-wear analysis confirmed the central role of grinding tools for cereal processing, the complexity of the various stages of cereal preparation, and the adaptation of this equipment and techniques to prepare different final products. It also highlights the important cultural and symbolic meaning of these tools in the general LBK and BVSG cultural systems. However, the question of whether grinding tools were specialized or not, is only partly answerable through this method. To obtain a more accurate view of the range of plants processed with these implements, microbotanical residue analysis was added to our functional approach.

3.2 Starch grains analysis

First of all, it should be noted that there was no evidence of starch grains in the 16 control sediment samples studied. Although we are currently unable to assess whether this is typical for Paris Basin contexts as no other such studies exist, we can reasonably expect that the starch grains reported here to not be ancient contaminants, but instead be evidence of Early Neolithic plant processing activities (see also Haslam 2004). This statement is of major importance to attest that the residues observed and collected from the surface of the tools were directly linked to the use of the grinding tools.

Out of the 29 tools samples, all contained some evidence of starch grains, albeit in different amounts. A total of 376 starch grains (not including clusters of amorphous starch) were recovered. Out of these, 153 could not be identified further for two main reasons, the first due to the grains presenting extensive damage (22.9 %) that includes crushing or gelatinization, the second is that they did not match any of the grains in our reference collection (17.8 %). A total of 7 taxa were identified, and two other general categories were created: Cerealia (which includes wheat and barley) and USOs. The grinding tool with the largest number of grains (n=82) is the one from Ath (st. 12 sq. B4 tool 1), as the other tools contained between 1 (e.g., Tremblay-en-France ISO 408) and 38 starch grains (Verson St. 95 n°6517).

Based on the study of 29 grindings tools (Tab. 2), the starch grain data indicates that their main function was indeed to process cereals; a result also supported by the use-wear analysis. However, the grinding stones were not solely used for this purpose, as we see the presence of other plants, namely legumes and USOs in minor quantities, which provides additional support to assumption that grinding stones were not all specialized for cereal processing.

The presence of cereals was nearly ubiquitous in the samples studied. Starch grains of wheat (Fig. 5a b) was found on objects from all the sites, except for Remicourt. Barley (Fig. 5c-d), another type of cereal, was also found in small quantities, from Loison-sous-Lens, Menneville, Ath, Berry-au-Bac, and Choisy. Unidentifiable cereal grains, either belonging to the two species of wheat (einkorn or emmer), or barley, where placed in a separate category "Cerealia". These were frequently encountered on the tools, but due to extensive damage, either as a result of mechanical action or exposure to heating, could not be identified further (Fig. 5e-f). Finally, one possible oat starch grain was recovered from Ath (Fig. 5. g-h).

Fabaceae starch grains, including those belonging to peas (Fig. 6a-b), were recovered in smaller quantities from sites Verson, Ath, Berry-au-Bac, and Choisy. USOs were more common, with their presence on at least one object from each site studied (except for Choisy, Fig. 6c-d). Wild plants, probably belonging to wild foxtail millet (*Setaria* sp., Fig. 6e-f), were also found on numerous tools. It is unclear whether these weedy plants that commonly grow in cereal plots found their way accidentally or purposefully in the diet of the ancient populations. The processing of acorns was not identified in these samples.

Finally, the presence of cooked starchy masses (also known as amorphous starch) was frequently encountered on the tools included in this study (Fig. 6g-h). We would argue that this could indicate that cooked foods were readily processed on the tools. However, we cannot exclude that these damages are not the result of grain cleaning or dehusking prior to grinding; further experimental work is clearly necessary to address this issue and to test whether we can differentiate between cleaning (dehusking) and the actual cooking of cereals. For the most part, the masses cannot be identified to a specific taxon (except in very rare cases). However, individual grains, that may have undergone cooking, were also encountered in these samples. In such cases, it is sometimes possible to identify them to genus/species. Beyond this general pattern, an interesting observation was made on three artifacts from Ath, Verson, and Berry-au-Bac, where evidence of cereal sprouting was identified. These were also recovered from objects that have larger quantities of starch grains overall, and therefore it is unclear whether their presence is the result of a larger sample size.

The identification to species of wheat is not straightforward, and only in one instance was it possible to suggest that a specific species was used. For the most part, wheat (either *Triticum monococcum* or *T. dicoccum*) was used. Based on the starch grain data, legumes (and especially peas) were consumed and seem to have processed, with the aim to either crush or grind them. With regards to wild plants, this is probably the question that remains the least answerable. Small-seeded wild plants such as fat-hen, chickweed (*Stellaria media*), and annual meadowgrass (*Poa annua*) produce very small, rather non-diagnostic starch grains (Cagnato et al., in review). Therefore, while it is clear that wild plants were present in the samples, it is not possible at present to identify these further. Finally, oily plants such as flax and hazelnuts were not identified due to the absence of starch grains in these seeds.

3.3 Phytoliths analysis and other microfossils

3.3.1 Control sediments

The content of the embedding sediments was compared with the results of the samples from the active surface of the grinding tools. This work was only possible for the sediments related to the tools from Tremblay-en-France (Iso 110 and 408), Menneville (St. 617), as well as the hoard pit of Berry-au-Bac. Phytoliths are absent in the sediments, except for the tool in which the Tremblay-en-France (Iso 408) grinding stone was found. In this sample, elongate (39 on the grinding stone and 22 in the sediment) and rectangular (39/11) morphotypes were identified. These very common morphotypes with low indicative value could be (naturally?) present in the sediment. No Pooidea inflorescence or woody dicotyledonous morphotypes were found. This observation supports the idea that the data obtained from the samples collected from the active surfaces reveal in fact the plants processed on the grinding tools and are not the result of contamination (Portillo *et al.*, 2013, 2017; Procopiou 2003). The method used to extract the phytoliths using acid may also be questioned (Jenkins 2009).
The presence of fibers in the control sediments led us to review the slides and carry out a more detailed examination: the results are presented in Table 3. The frequencies and types of fibers are different between the sediment and the samples taken from the active surfaces, which allows us to once more eliminate any form of contamination between the tool and its context. These observations fit with the absence of starch grains in the comparative sediments.

3.3.2 Results

Table 4 highlights the different phytolith morphotypes observed on the slides as well as their absolute frequencies. It was not possible to calculate all the relative frequencies as the number of phytoliths was insufficient for a statistical study. A few pollen grains, spores of decomposer fungi and, in larger numbers, spores of Pteridophytes from various fern taxa, were also recorded. On some slides the fibers could be counted, however, when they were found to be more numerous, and bundled and tucked away, a frequency indicator was used instead. The presence of microfossils is also indicated, in particular freshwater algae (diatoms) and sponge spicules.

-Cereals
Phytoliths belonging to the vegetative organs of Poaceae are only present on the objects studied at the sites of Tremblay-en-France, Verson, and Ath (fig. 7). The rondel and bilobate types indicate the presence of Pooideae and Panicoideae. Inflorescence phytoliths are few in number: 1) silicified articular cells are not determinable, 2) the elongate dendritic cells are often fragmented and those that are whole are not numerous enough to permit a morphometric study. If their shape and measurements led us to identify cereals, it is not possible to specify which ones.
Excluding taphonomical considerations, the morphotypes present seem to indicate the grinding of grains not yet completely separated from their husks after winnowing. Finally, the presence of a few grains of Chenopodiaceae pollen cannot attest to its consumption.

-Fern spores (fig. 8 a, b, c, d, e, f)
Fern spores are present in the residues of five tools and do not belong to the same taxa.
The reference collection of the Musée de l'Homme as well as the reference atlases of Maurice Reille (Reille 1995, 1998, 1999) were used for their identifications. The diameter of the spores, their shape, and the ornamentation of their walls (exine) have been taken into account. The spores are often poorly preserved and therefore difficult to identify precisely. Their distribution and ecology being different, we can exclude pollution.
Due to these ferns not being able to naturally develop at the sites in question, we would argue that their presence is the result of human actions.
Thus, the residues on the tool from pit 110 in Tremblay-en-France, revealed the following types:
- *Asplenium trichomanes* tp, a small fern that today grows on walls and is used as a remedy for respiratory pathologies.

- *Adiantum capillus-veneris*, known for its properties in traditional medicine, is the subject of much research in pharmacology to extract its active principles (Rastogi *et al.* 2018: 101-119; Dehdari and Hajimehdipoor 2018:188-197). We will only mention its potential to aid with respiratory functions.
- A third type of spore is present; its wall is thick. The photographs obtained under the microscope using varying focal points are difficult to synthesize and we will therefore not risk an inaccurate identification.

The sample from Verson (St. 35 n°6517) contained three spores, also thick-walled, for which no identification is proposed.

In Ath the following taxa have been identified:
- *Thelypteris palustris*, which is specific to humid areas as its name indicates, is non-toxic and has no particular use, its young shoots are consumed by certain cultures located far from the Paris Basin (Herrick 1997).
-The single *Botrychium* spore could not be identified to species.
-*Diphasium complanatum* tp, a synonym for *Lycopodium complanatum* tp., has curative properties, especially seen in its hemostatic and antiseptic spores when applied to wounds (Quattrocchi 2012).

At Berry-au-Bac, the spores are present on two of the grinding tools, unidentifiable on 598/3, they appear on 598/4 as belonging to the species *Dryopteris filix-mas*, common and not very demanding, it develops in humid areas. Its fronds as well as its rhizomes have medicinal properties (Couplan 2009). The male fern (*Dryopteris filix-mas*) rhizome and petioles at the base of the leaf have anthelmintic properties which is one of the best remedies against taenia; in veterinary medicine this plant is used to fight liver fluke (Perrot 1974; Jahns 1989, Bui Thi *et al.,* 2008)

-*Fibers and Urtica epidermis* (fig. 9)
Some grinding tool residues have a significant amount of cellulosic or poorly lignified fibers. The morphology of some of them led us to compare them with flax and nettle fibers, the closest to fossil ones. Originating from stems, these bast fibers are difficult to identify because their surface characteristics are very similar. Numerous authors (e.g., Luniak 1953) have worked on the shape and size of the cross-sections of the fibers; however they appear very similar and therefore cannot be used for discrimination purposes. It should also be noted that in our slides no cross-sections could be observed.
X-ray micro-diffraction (Müller *et al.* 2006) allows to identify the samples accurately, but the use of a synchrotron system limits its application. A protocol described by Bergfjord and Holst (2010: 1192-1197) is based on the orientation of the fibril in polarized light microscopy and the detection of the presence of calcium oxalate crystals in combination with the fibers. According to the authors, this method requires little material, which is a great advantage.
Concerning the fibers studied, their shape and diameter are consistent with those of flax and nettle, some shapes may suggest calcium oxalate crystals which are not present in flax, but these may have been destroyed during the phytolith extraction protocol in nettle fibers. Not all fibers observed belong to nettle, however, as many fibers accompany the conductive tissues of plants and are not currently identifiable. In the residue samples, a fragment of *Urtica dioica* leaf epidermis was found.

-*Conducting units: vessels and tracheids* (fig. 8 g, h, i)
Wood is a complex tissue characterized by the presence of functional elements such as cells or rows of dead cells with lignified walls. Sap-conducting vessels can be punctuated or kept open by ringed, spiral, or reticulated enlargements. The presence of numerous punctuated vessels attests to woodworking and supports the identification of wood or bark phytoliths in Tremblay, Verson, Ath, and Loison-sous-Lens.

-*Phragmites epidermis* (fig. 8j)
A single fragment of *Phragmites* sp. (common reed) leaf epidermis was observed. This easily accessible raw material could have been used in the domestic and artisanal activities of the inhabitants of Choisy-au-Bac.

-*Glomus*

As highlighted in Table 2, the fibers observed in the residues are often related to particularly resistant organic material - they are not softened by chemical treatments and do not crush when mounted between the slide and cover slide. Moreover, we observed *Glomus* sp. chlamydospores connected by their hyphae to the organic material (fig. 10). *Glomus* is an endomycorrhizal fungus: a mycorrhiza is the result of a symbiotic association, called mycorrhization, between fungi and plant roots, in this special relationship, both organisms benefit from the association from a nutritional point of view. On the other hand, many mycorrhizal fungi live in association with the common reed. In the control sample associated with the grinding tools deposit, we found no evidence of *Glomus*. This particular observation would allow us to consider that roots were processed on the querns, but no further identification can be made as to the type of roots that were used.

4. Discussion

Our integrated approach reinforces the interpretations and reduces the methodological limitations that arise when each analysis is taken separately. It also proposes a more complex vision than initially expected on the uses and life cycles of grinding tools in daily food preparation.

4.1 Advantages and limits of each method

Table 5 sums up the level of information brought by each type of analysis for the different kind of plants and processing, while table 6 compares the main results obtained with each analysis. Use-wear analysis brought crucial information on the nature, but also state (wet, dry), and type of preparation (heating, dehusking) of the transformed matters, especially cereals. On the other hand, microbotanical residues are more informative to discuss the families of plants processed and if several matters were processed by a grinding tool. They were particularly relevant to identify the secondary processing of legumes and USOs that had not been identified by use-wear analysis. This is probably due to the main use of the tools for cereal grinding, and to the faster development of the related use-wear traces.

In our context, the content of the sediment directly adhering on the grinding tool surface bore little to no contamination from the surrounding soil, which ensured a high level of reliability of the data obtained and on the functional interpretation. On the contrary, the nature of the sediments and most probably the regional climatic conditions were not as good for the preservation of both starch grains and phytoliths as in other contexts, especially dry ones. This constituted a limit to the analysis. Moreover, part of the residues were impossible to identify, for the starch grains this amounts to 40% of the entire sample. As we previously mentioned this is due to an important number of starch grains presenting damage, and to a lesser degree because they did not match the starch grains in our current reference collection. The presence of damaged starch grains further confirms their antiquity and function of the tools studied. The starch grains that remain unidentified likely indicate that a larger number of taxa were in fact processed by the LBK/BVSG populations.

Starch grains appear as excellent markers to document the processing of cereals, legumes, and some wild plants, generally at the genus level but sometimes at the family level. Another category that is also well documented includes underground storage organs. Starch-grains also provided reliable information to identify heating processes, as well as sprouting. On the other hand, phytoliths and other microresidues allow us to identify quite precisely the different stages of cereal dehusking. As revealed by the phytoliths study, the presence of ferns, vessels, fibers, and leaves also sheds light on plant use unknown to date.

4.2 Which plants were transformed?

Microbotanical residues allow to identify the processing of a wide range of plants, some already confirmed by macrobotanical remains (cereals, legumes, chenopods), but also new plants that were unknown or underestimated in the assemblages until now (USOs, ferns, urticae, etc). The panorama of plant processing in the Early Neolithic of Western Europe appears at last much richer and diversified than initially expected.

- *Cereals*

The combination of the three sets of data confirms that cereal processing was the main function of the grinding tools. It was possible to identify more precisely emmer and barley through macrobotanical remains and starch grains analysis.

In the hoard at Berry-au-Bac, use-wear analysis of the grinding tools stressed their major use for cereals processing. While starch grains belonging to cereals were found in large quantities, the phytoliths study did not reveal their presence. This would suggest that these tools were used for grinding very clean grains, probably after a first stage of dehusking carried out with wooden mortars or other tools. In the case of Remicourt (st. 258), the grinding stone was identified as having been used for cereal grinding, but the starch grain analysis revealed only two indeterminate cereal starch grains. The remaining grains were too damaged to say anything else.

The starch grains identified generally fit with the results of the macrobotanical remains and highlight the processing of wheat and barley. The discovery of one starch grain of *Avena* in Ath is peculiar, as it is not known in Early Neolithic contexts in the region. The presence of oats has been only mentioned by Chevalier and Bosquet (2017) on tools from Remicourt. But with regards to the starch grains, it is not possible to differentiate clearly between domesticated oats (*Avena sativa*) and wild species (e.g., *Avena strigosa*) due to similarities in size. Similar difficulties arise when trying to differentiate between macrobotanical remains of oats. Regarding the presence of *Avena*, it is reported in Neolithic contexts in north and central Europe; specifically, *A. strigosa* is documented in Late Neolithic contexts in France (Fairweather and Ralston 1993). However, considering that domesticated oats are clearly attested in Europe starting in the Bronze Age (Zohary *et al.* 2012), it seems more plausible that the starch grain recovered may belong to a wild species of *Avena*.

- *Legumes*

According to the use-wear analysis, legumes were not the main plants processed on grinding tools with a back-and forth motion. However, some evidence of legume processing was occasionally found: a few starch grains belonging to the Fabaceae family, and more specifically to peas (*Pisum* sp.) were identified on the surfaces of the grinding stones. Their presence could be related to occasional grinding of legumes on stone tools, or their mixing with cereals in different types of food preparations, as ethnographically reported in Morocco for example (Peña-Chocarro *et al.* 2009).

- *Wild plants*

Our study did not recover any evidence for the processing of acorns. In the same way, acorns are rare in Neolithic macro-remains in northern France and Belgium (Bakels 1984; Salavert 2011). Use-wear appears much less efficient to detect the processing of (wild) grasses. This constitutes one of the weaknesses of use-wear analysis, as the component of these kinds of plants do not alter significantly the stone surfaces. However, other wild plants have been occasionally identified by starch grains or phytoliths analysis. The presence of Paniceae tribe (e.g., *Setaria sp.*) on at least one third of the samples suggests that the processing of cereals could involve weedy plants. Moreover, a few Chenopodiaceae pollen grains were found. This would suggest that the products of harvesting were not sorted nor completely cleaned prior to their consumption. One of the objects from Choisy lacked cereal markers, from a use-wear and starch grain perspective, but the latter indicated the presence of *Fabaceae* family taxa, and wild plants. This could indicate a real diversification of the use of grinding tools during this period, for example, for the processing of a wide range of other plants.

- *USOs (tubers, rhizomes, roots, and bulbs)*

Notably, in this study, we were able to determine the rather frequent presence of USOs only through starch grain analysis on most of the samples analyzed. This would suggest the rather frequent use of querns for the processing of root and tubers, to obtain flour. While it is clear that USOs were processed on a number of the tools studied, their taxonomic identification has been hampered by several factors. The first is that none of the tubers recovered in our archaeological samples match the ones we currently have in the reference collection. The second is that since we lack macrobotanical evidence of tubers in Early Neolithic contexts in the Paris Basin, it has been difficult to further develop the reference collection (see Cagnato *et al.*, in review). However, when we consider slightly adjacent areas beyond the Paris Basin, a variety of USOs have been reported, and this is especially true for Mesolithic contexts in the Netherlands and Denmark, but also Neolithic sites in central Europe, where they are found in macroremain assemblages (Klooss *et al.* 2016; Kubiak-Martens 2016). Our USO starch grain identification highlights the importance of wild plant harvesting in the Neolithic in this part of Western Europe and falls in line with other areas of the world where USOs were readily processed using grinding stones (Fullagar *et al.* 2006; Liu *et al.* 2014; Piperno *et al.* 2000). Finally, as many of these starch grains are damaged, likely as a result of being exposed to heating and subsequent grinding, their original shape and size has been difficult to determine. However, it is clear that different types of USOs are represented in the samples: at least 3 types seem to be present. Ongoing work on expanding the reference collection may aid in narrowing down their identification.

The presence of *Botrychium* starch grains, in association with those of *Typha*. has been detected on grinding material from the Gravettian sites of Kostenki 16 in Russia and Pavlov VI in the Czech Republic (Revedin *et al.* 2010: 5-18). The authors specify the richness of starch in *Botrychium* roots and the fact that they are easy to grind.

-Ferns
Ferns have been surprisingly identified with high frequency through the presence of spores preserved in the phytolith samples. While these plants grow in specific ecological conditions, they appear to have been brought to the sites by humans. The diversity of the types of ferns identified suggest their varied uses, especially with regards to their leaves, for food preparation or possibly for medicinal purposes**.** Ferns are traditionally used to cure a large range of pathologies under different forms (direct application, extraction of active principle, etc.). This observation is particularly true for the two deposits at Berry-au-Bac and Ath.

-Fibers
The presence of high quantities of vegetal fibers has only been recognized at Berry-au-Bac. The morphology of these fibers suggest they could belong to nettle. In addition, one phragmites leaf epidermis (common reed) was found at Choisy-au-Bac. If nettle was indeed used, we cannot specify the reason: food, textile or even therapeutic (Delahaye 2015). Besides, we also need to question their relationship with the function of the grinding tools. As the grinding tools from Berry-au-Bac were recovered from a storage deposit, we suggest that these fibers could be the result of a (nettle) mat deposited together with the grinding stones and packing tools in the same pit. This mat would have been placed beneath the grinding stones during grinding to recover the final product and protect it from soil contamination.

-Wood and bark
Wood and bark contain relatively few phytoliths and many of these phytoliths have variable morphologies and cannot be uniquely identified to specific taxa (Tsartsidou *et al.*, 2007). If most of them are not specific to dicotyledon wood and may be in fact present in herbaceous plants, fruits, and nuts (Albert *et al.*, 2016) there are however certain phytoliths indicative of wood and bark, differences in the cellular composition of their tissues should become manifest in the production of different phytolith morphotypes (Collura and Neumann, 2016).

Regarding the general use of querns, the presence of a few wood and bark elements is highly interesting. At first glance, it could suggest a possible contamination of the samples from the surrounding sediment. Alternatively, their presence on the grinding surfaces could be explained by the fact that grinding of wood and bark, to obtain powders with coloring or medicinal properties, was carried out. The bark of pedunculated (*Quercus pedunculata* Ehrh.) and sessile (*Quercus sessiliflora* Salisb.) oaks are used and commercialized in powder form for their dyeing principles, whose tannins give off colors ranging from beige to those seen in dead leaves. Powdered alder bark also provides different colors depending on the type of treatment (Cardon 2003, 318-330). We should not discard the possibility that the grinding stones may have also been used for fruit processing.

4.3 Treatment and transformation techniques

-Grinding / dehusking of cereals and legumes
According to our existing experimental reference collection, use-wear analysis can detect if the grains processed were very well cleaned (cereal grains completely or partially dehusked), humidified, or even roasted prior to their grinding.
According to several experimental tests, it is highly possible to differentiate the processing of cleaned and hulled cereals by use-wear analysis (Hamon 2006, Meurers-Balke and Lüning 1999). As a matter of fact, the phytoliths contained in the hull of cereals impacts significantly the formation of use-wear traces, especially the characteristics of the micropolishes. Though our samples studied here do not seem to have been used for such actions, this has been identified at other contemporary sites. Previous results also suggested that Early Neolithic farmers were consuming partially dehusked and cleaned wheat and barley (Hamon 2008, Hamon *et al.* 2011).
From a general perspective, the high rate of fragmented elongated phytoliths suggests that a mechanical action was at the origin of these processes. In Ath, the presence of broken elongated phytoliths would indicate that grains together with some of their glumes were processed on the grinding tools.
Starch grains are more telling of processes that involve grinding rather than dehusking. Experimental tests carried out by the authors determined that dehusking did not necessarily leave significant amounts of starch grains on the tools (Cagnato *et al.*, in press b). However, grinding, when carried out on rather clean cereal grains, but also legumes and other types of seeds, leaves an important quantity of damaged starch grains (Babot 2003; Li *et al.* 2020; Ma *et al.* 2019). For example, our own experimental grinding of cereals (barley and wheat) showed fissured grains (either in half or with broken edges), surface damage, and extinction crosses that are no longer distinct (Cagnato *et al.*, in press b). In addition, protrusions seem to form in some grains after extensive grinding (seen especially in wheat). Pulses such as lentils and peas, which we also experimentally ground, were also frequently broken, with fissured edges, and with partially damaged extinction crosses.

-Heating / humidification
Heating and/or humidification of the cereal grains prior to their processing with grinding tools is an ethnographically documented custom, to facilitate dehusking of cereal grains with stone rather than wooden artifacts (Lundström-Baudais *et al.* 2002; Meurers Balke and Luning 1999; Hamon and Le Gall 2013; Alonso 2019). In the absence of wooden tools preserved in our archaeological context, the question of their use or not by the first farming populations of the Paris Basin is of upmost interest.
From a use-wear analysis point of view, humidification and heating of cereal grains imply different patterns. Humidification implies the development of a pelliculla on groups of crystals and thick smoothing on the surface (Hamon 2006). On the contrary, the roasting of cereals prior to dehusking or grinding to prepare special recipes improves the abrasiveness of the grains and has consequences on the levelling of the microrelief. The results obtained show that a significant part of the grinding tools were used to process wet cereal grains, though it is difficult to attest that the grains were soaked in advance rather than adding water during the grinding itself. While simple humidification of seeds prior to grinding will not be detectable in terms of starch grains, the presence of freshwater algae (diatoms) and sponge spicules on the surface of the tools provide evidence for the use of water during this process.
Exposure to heat clearly affects starch grains, which begin to swell at lower temperatures (< 70 °C). Once higher temperatures are reached, changes take place rapidly and the structure of starch begins to further distort, eventually disintegrating into clusters of amorphous starch. The high frequency of such elements in our samples suggests that cooked plant foods were subsequently processed on the tools, either for mashing, or alternatively, to combine with other plant foods. The presence of starch masses, some visibly surrounded by a differently colored substance, makes us question whether these starch-rich plant parts (tubers, seeds) were cooked not simply in water, but perhaps even in oil/fat. Experimental tests have shown that wheat and peas, fried in animal fat and vegetable oil, leave similar yellow masses (Chantran and Cagnato, accepted.). However, additional experiments will be necessary to determine whether other types of cooking practices also leave similar traces. The presence of these starch masses also questions the use of querns as tables for the mixing of food, similarly to the use of *metates*, which are used to prepare the *masa* (maize dough) for subsequent tortilla elaboration (Searcy 2011).

-Sprouting

Another type of process, which includes the steeping of seeds in water for longer periods of time (several days), will often result in sprouting, also known as germination or malting. In this scenario, starch begins to be digested, leaving characteristic traces on the surfaces of the starch grains. In our samples, sprouting was especially identified on Triticeae tribe starch grains by the presence of small pits on the surface and missing concentric rings (see Wang *et al.* 2016). It remains unclear what the purpose of sprouting was: in the archaeobotanical literature, sprouting is often considered as a first step to fermentation. However, sprouted cereals could have been accidentally processed, or even purposefully included. Although the health benefits of sprouting are inconclusive (see Lemmens *et al.* 2019), sprouting clearly changes the biochemical and nutritional properties of cereals. These changes are often species-specific, but include diminished starch content, increased vitamin content, an increase in protein solubility and hence digestibility, and grain softening (Lemmens *et al.* 2019).

4.4 Regional and chronological variability

The analysis of the starch grains and phytolith remains recovered from different sites suggest varying conditions of preservation (Hamon *et al.* 2011). Actually, the alluvial Aisne and Oise Valleys do not provide the best conditions for the conservation of microbotanical remains. The type of sediments in which the tools were buried seem to highly influence the preservation of remains, and modify the quantities preserved, rather than the diversity of taxa.
Indeed, the function of grinding tools display the same general pattern throughout the whole sequence. No important differences in the types of plants, nor kind of treatment seems to differentiate LBK and BVSG tools. However, the two narrow basin querns from the Cerny site of Choisy-au-Bac suggests a shift at the end of our chronological sequence. The change in the characteristics of grinding tools, with reduced dimensions and more circular motions, seems related to a change in the types of plants processed, with a decrease in the processing of cereals.

Our combined use-wear and residue analysis confirm the observations already made on the main use of grinding tools for cereal processing, but also provides brand new clues concerning the multifunctional use of these tools in the frame of plant transformation. As already stated, one cannot reduce the presence of grinding stones to the grinding of cereals, and even more to food preparation. The diversity of plant remains as recovered on grinding stones suggests not only their use in the different stages of cereal processing, but also suggest uses for medicinal or dyeing purposes. The difficulty lies therein in the temporality of these simultaneous or successive different uses. Microbotanical residue analysis cannot be used to determine the frequency of plant use, instead, it is based on the presence or absence of plant taxa. While the study of microfossils can indicate the multifunctionality of tools, it cannot assess whether the tool was used for different activities *at the same time.* Here, technological observations are of major importance to identify if grinding tools display evidence of reuse, after a phase of reshaping or fragmentation for example. Our study confirms the major importance of grinding tools in cereal processing, but also suggests cycles of specialization or multifunctional uses on a long term far beyond basic typological classifications.

The higher rate of functional specialization in cereal processing at typical settlements is even more pronounced when taking into account the type of households to which they are related. The deposit of some paired querns and grinders in the BVSG refuse pits of Loison demonstrates the very high variability of intensity and duration of use from one instance to another within one occupation horizon (Praud *et al.* 2018: 194). Following recent proposals on the structure of household organization of LBK settlements (Hachem and Hamon 2014; Gomart *et al.* 2015), grinding tools tend to be more numerous and specialized in the processing of cereals in larger houses that in those that have more recently been built in a village. This fits with the general model of long houses being more anchored in the agricultural mode of production and welcoming more inhabitants. This specific status of cereal treatment is also visible in some grinding tool hoards. The technical and use-wear analysis of these grinding tools suggested complex cycles of use and reuse, but also underline the very long duration of use of some types of grinding tools with lateral or distal edges for the processing of cereals, especially for the LBK hoard found at Berry-au-Bac (Hamon 2006) and the BVSG one at Saint-Denis (Samzun and Hamon 2004) placed in dedicated pits inside or outside the houses. At Berry-au-Bac, the higher quantities of starch grain masses and of fern processing leads us to question a possible reuse of domestic grinding tools for special rituals prior to their burial, either for food preparation or medicinal purposes. Our results reinforce the possibly symbolic aspect of their deposit. More complex is the case of the enclosure of Menneville (Thevenet 2016) where a large quantity of querns were deliberately broken before being discarded into the ditch. The use-wear and residue analysis suggest that the final use of this grinding tool was not related to cereal processing. This would imply important recycling practices of broken querns for other secondary functions.

Conclusion

Together with use-wear analysis, the identification of starch grains, phytoliths, and other botanical elements is of great importance in the understanding of the material culture of different societies across space and through time in order to highlight the plants consumed and used as well as the functionality of archaeological artifacts, such as tools used in the processing of plants. Beyond the identification of the families of plants collected, processed, and consumed, interesting indicators appear concerning the different stages of plant treatment and preparation. For greater accuracy in the functional interpretation of grinding tools, future experimental works will be necessary, as ever, to better understand preservation biases of residues according to climatic, taphonomic, and mechanical conditions, while new methodologies of use-wear analysis will probably aid in improve to recognize the use of multipurpose tools. Nevertheless, our results and related methodological issues support discussions regarding the possible conservatism or innovations in vegetal food practices of Early Neolithic farmers inhabiting a region located at the most westerly point of the LBK expansion during the final centuries of this first wave of Neolithic expansion throughout the European continent.

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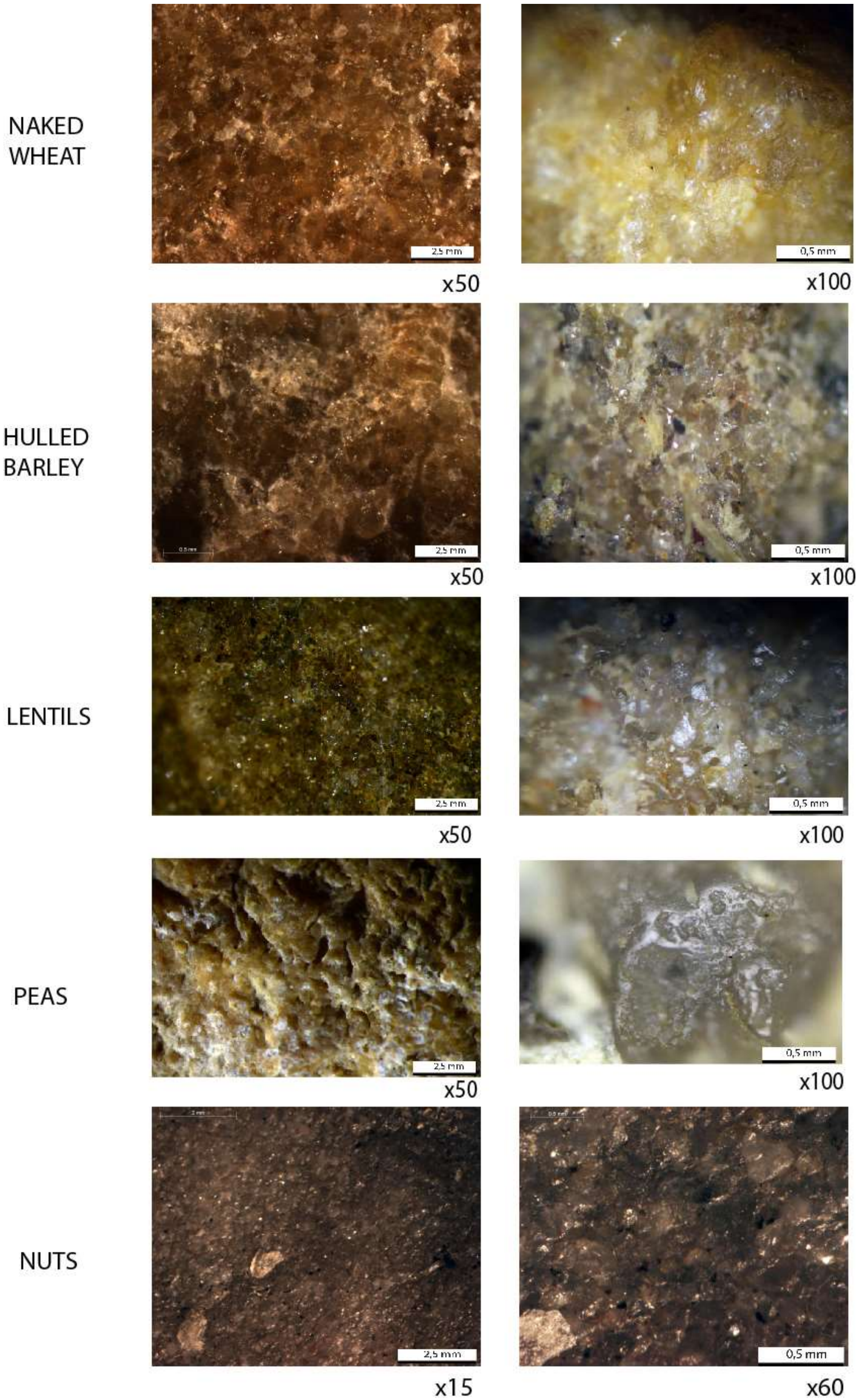
Figure 1. Map with LBK and BVSG sites mentioned in the text

Figure 2. Main use-wear traces at macro and microscale related to plant processing a. naked wheat: strong surface levelling, covering smoothing, grain rounding, micropitted micropolish; b. barley dehusking: lowly developed smoothing, grain surface alteration; c. lentils: levelling of the areas in relief, dull aspect, grains microchipping; d. peas: smoothing on the higher areas, smooth micropolish; e. nuts : levelling, grain smoothing, greasy film, shiny aspect.



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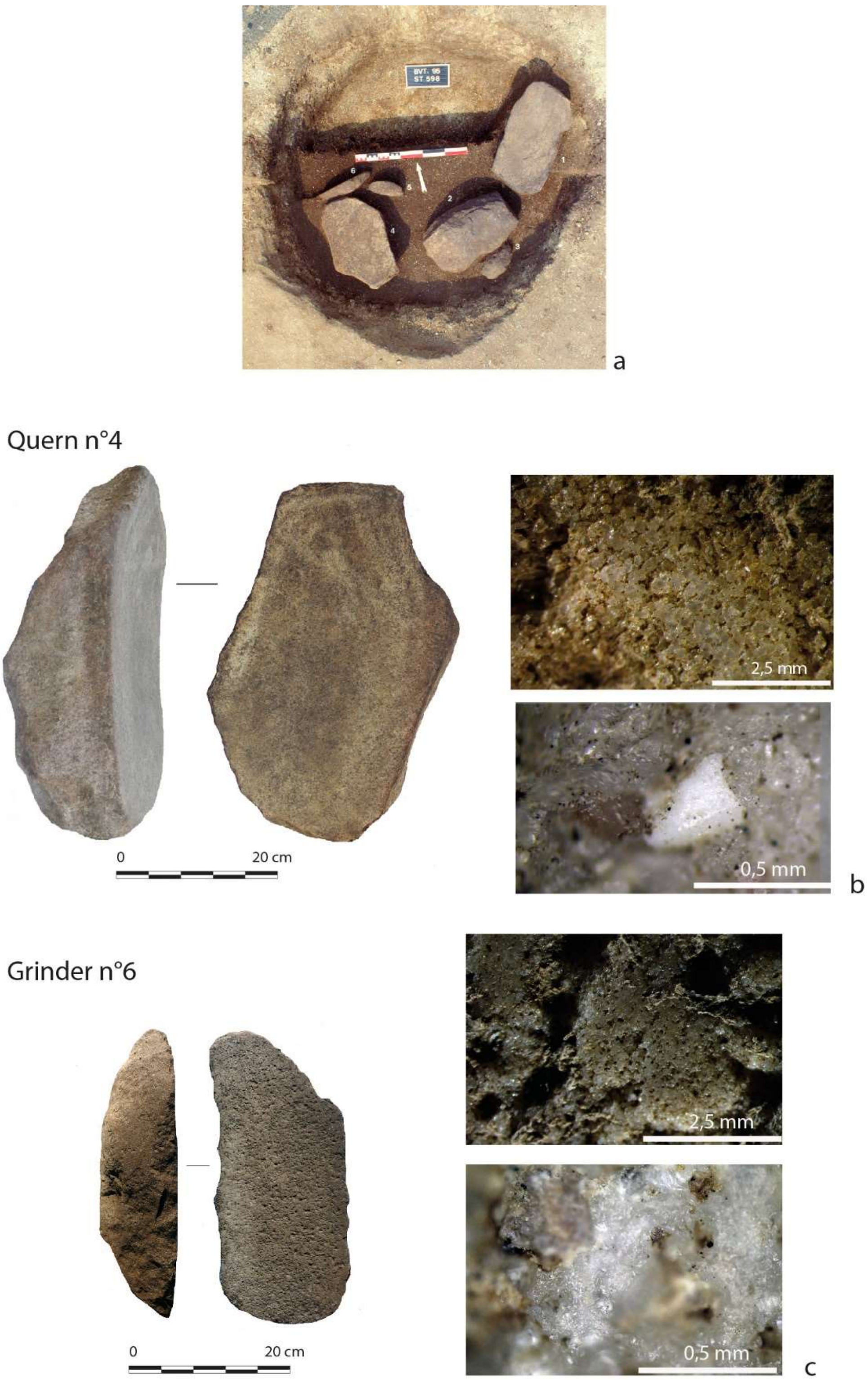


Figure 3. Grinding tools from Berry-au-Bac Le Vieux Tordoir and use-wear analysis a. the discovery of the hoard st. 598, including 3 querns and four grinders (photo: ERA 12 du CNRS), b. quern st. 598 n° 4 x40: strong levelling of the higher part of the microrelief, strong grain rounding, well-developed smoothing suggesting presence of water, and x200: micropitted micropolish developed on a feldspar grain with transverse striations characteristic of cereal grinding; c. grinder st. 598 n°6 x40: strong levelling in plateau, strong grain rounding, and well-developed smoothing characteristic of cereal grinding, and x200: micropitted and irregular reflexive micropolish that suggest on the contrary the processing of abrasive fine particles (photos C. Hamon).

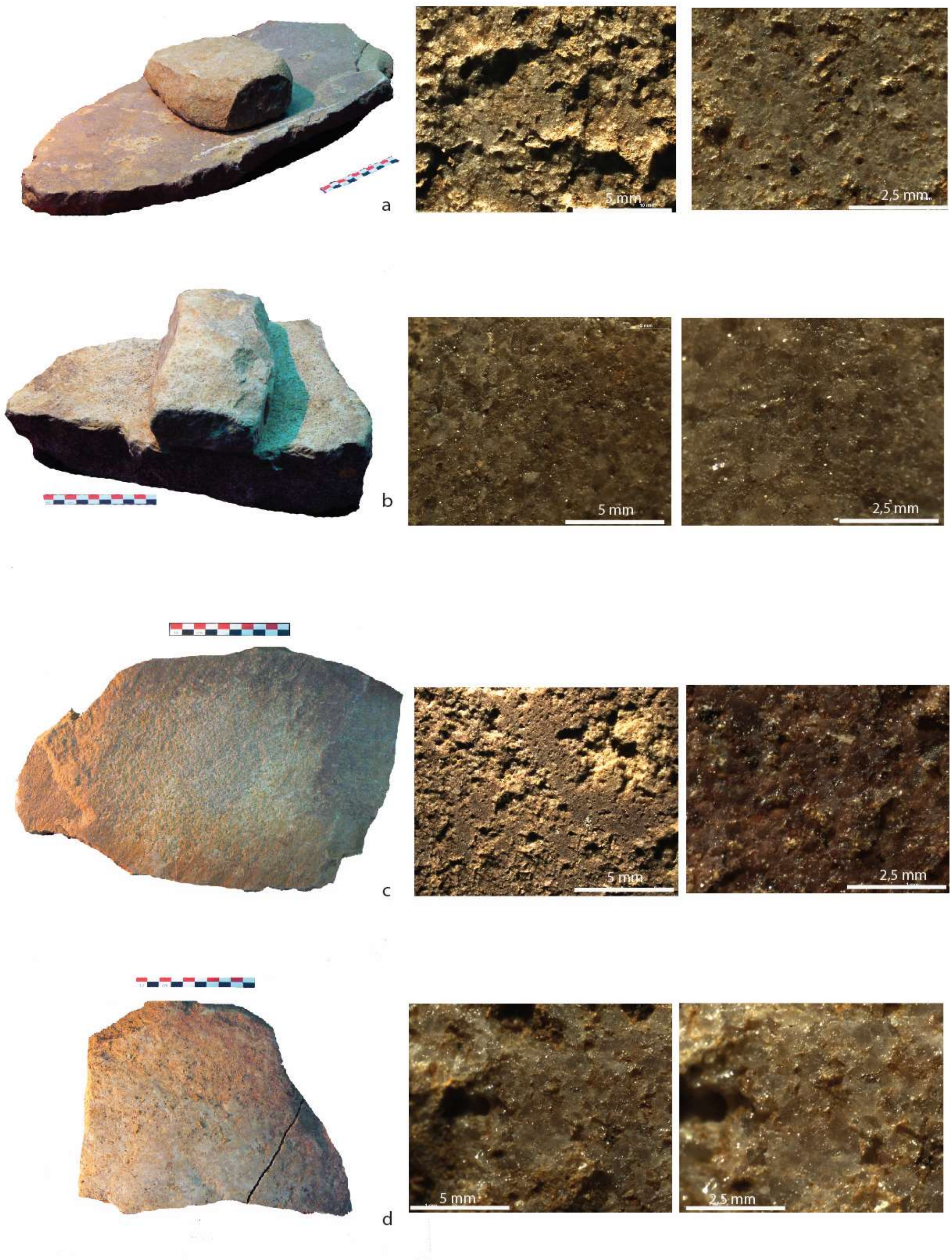


Figure 4. Grinding tools from Loison-sous-Lens and use-wear analysis a. quern from st. 1074, x 5 et x 50 : strong levelling in plateau covering smoothing and grain rounding characteristic of cereal grinding; b. quern from st. 1119, x 35 et x 60: very strong levelling, covering smoothing including in the interstices and moderate grain rounding characteristic of cereal dehusking ; c. quern from st. 11, x 5 et x 30: levelling in plateau, smoothing and moderate grain rounding characteristic of cereal grinding ; d. quern from st. 1008 : paired tools, x 30 et x 60: strong levelling and covering smoothing including in the interstices characteristic of a humid matter grinding, micropittted surface of the grains suggesting of mineral component (photos C. Hamon, after Praud *et al.* 2018)

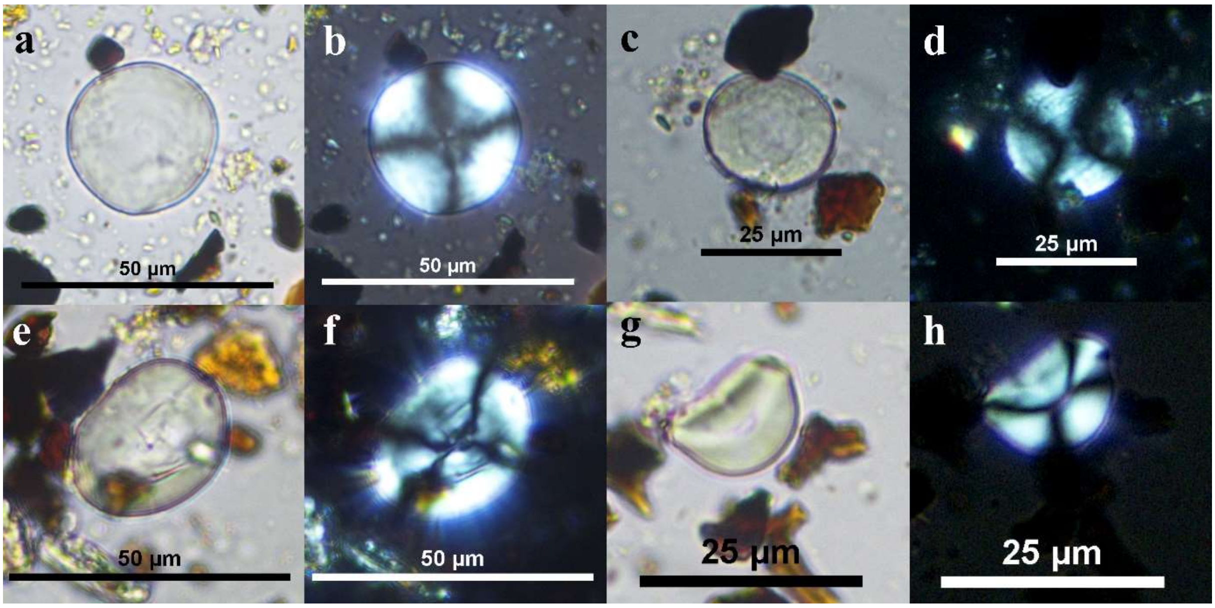


Figure. 5. Starch grains from cereals, shown in transmitted light and cross-polarized light. A-b) wheat (*Triticum* sp.) from Verson (St. 95 n°6517); c-d) barley (*Hordeum* sp.) from Loison sous Lens (St. 1119); e-f) unidentified cereal from Ath (St. 12 sq. B4 - Object 1); g-h) possible oat (*Avena* sp.) from Ath (St. 12 sq. B4 - Object 2) (photos C. Cagnato).

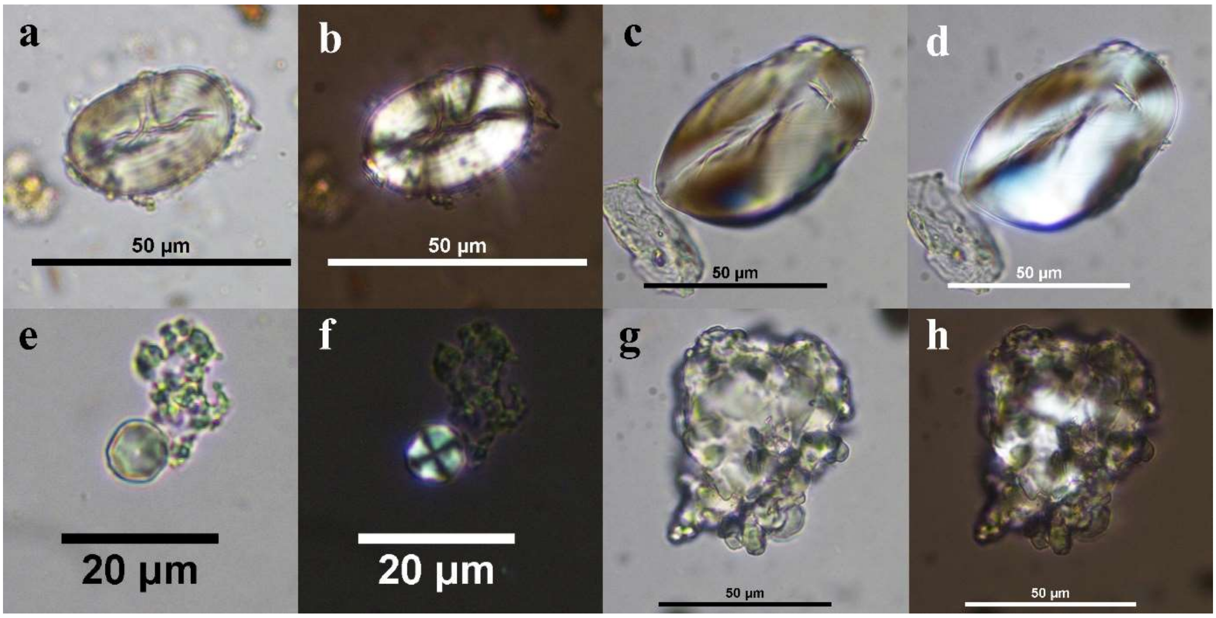


Figure 6. Starch grains belonging to other plants (i.e., besides cereals), shown in transmitted light and cross-polarized light. a-b) Fabaceae starch grain, probably belonging to pea (*Pisum sativum*) from Ath (St. 12 sq. B4 - Object 1); c-d) unidentified USO from Remicourt (St. 258); e-f) wild *Setaria* sp. starch grain from Loison sous Lens (St. 1074); g-h) starch mass from Loison sous Lens ("bloc gris") (photos C. Cagnato).

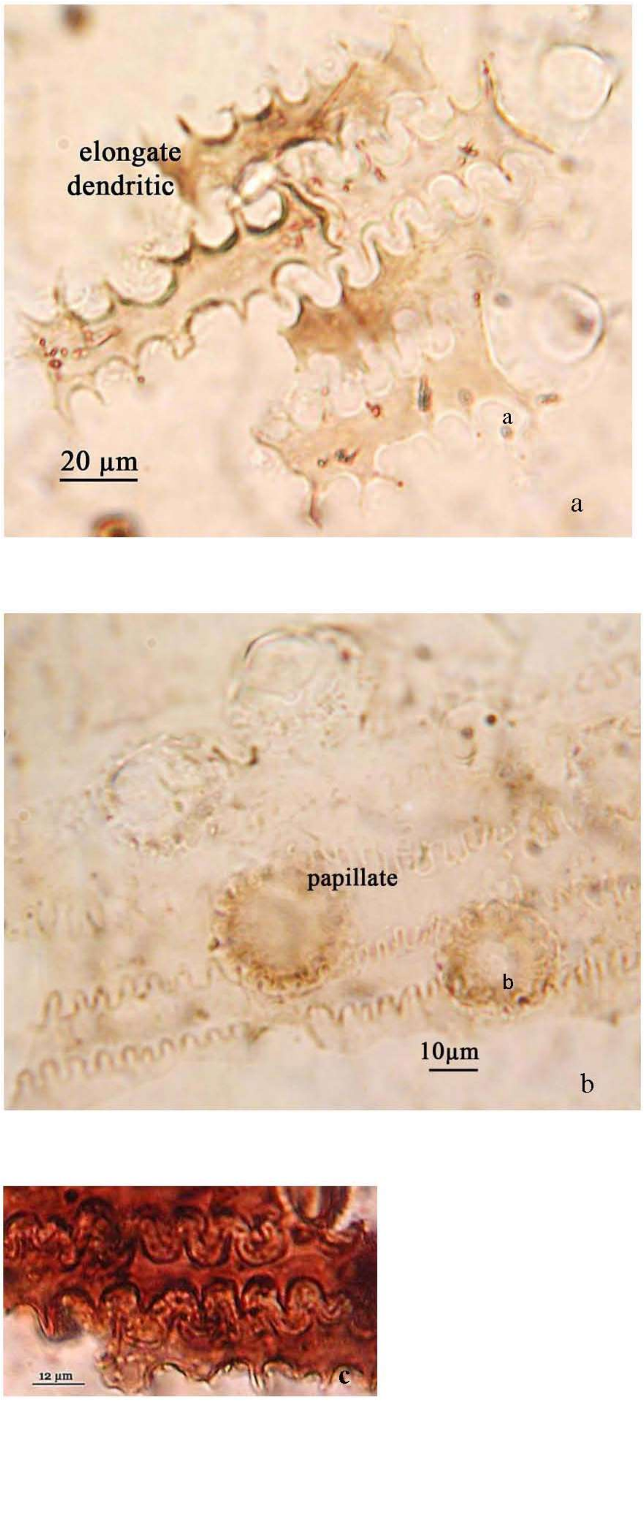


Figure 7. Articulated silicified epidermal tissues: a, b. *Triticum monococcum* (einkorn wheat), c. *Hordeum* sp. (barley) (photos A. Emery-Barbier)

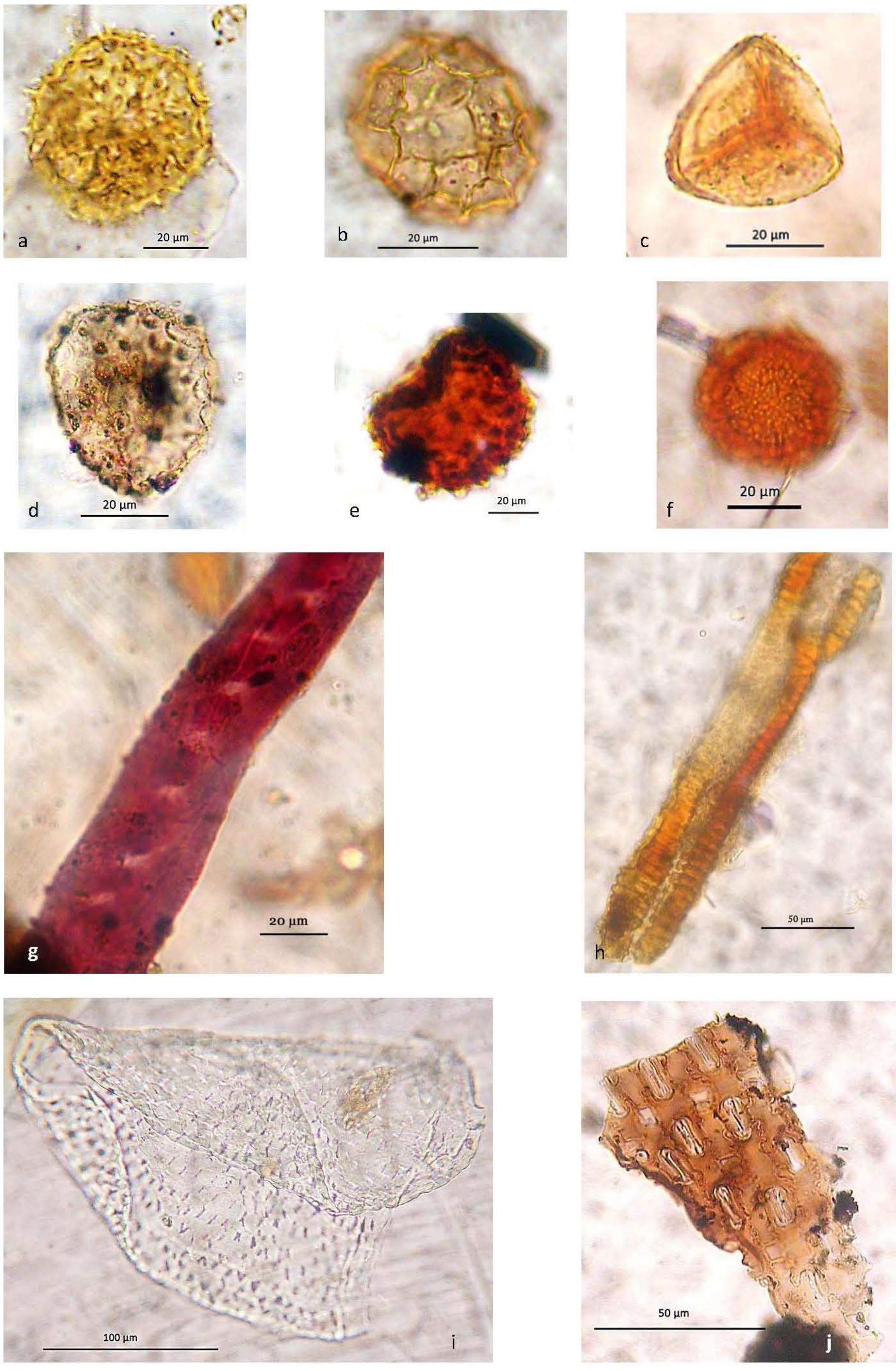


Figure 8. Pteridophytes spores and wood vessels a. *Asplenium trichomanes*; b. *Diphasium* / *Lycopodium complanatum*; c. *Adiantum capillus-veneris*; d. *Botrychium* sp.; e. *Thelypteris palustris*; f. undetermined ; g-i. punctuated sap-conducting vessels ; h. tracheid ; j. *Phragmites* sp. (common reed) epidermis (photos A. Emery-Barbier)

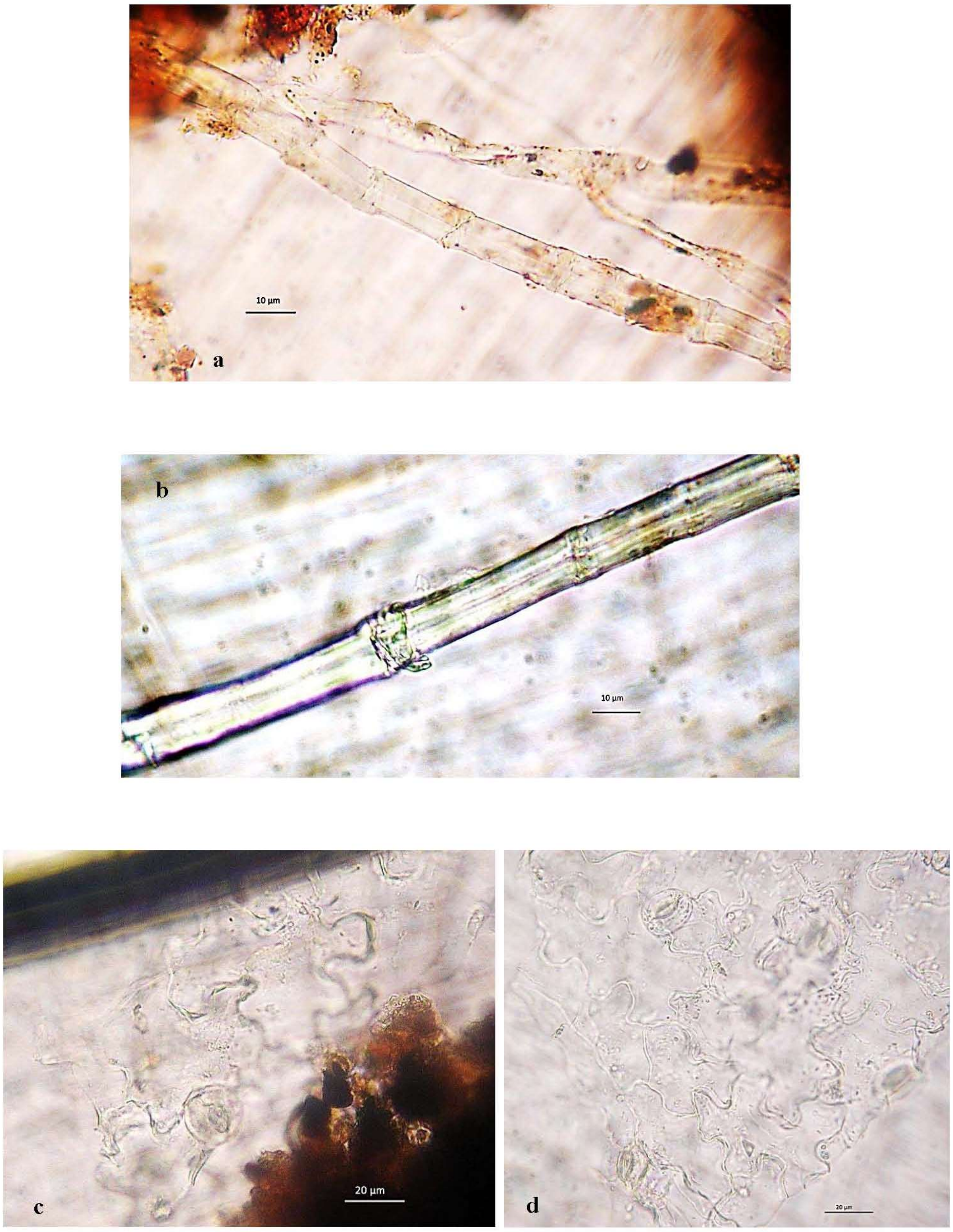


Figure 9. Berry-au-Bac le Vieux Tordoir st. 598 n°6: a. fibers; b. *Urtica dioica* fibers; c. epidermis; d. *Urtica dioica* epidermis (photos A. Emery-Barbier)

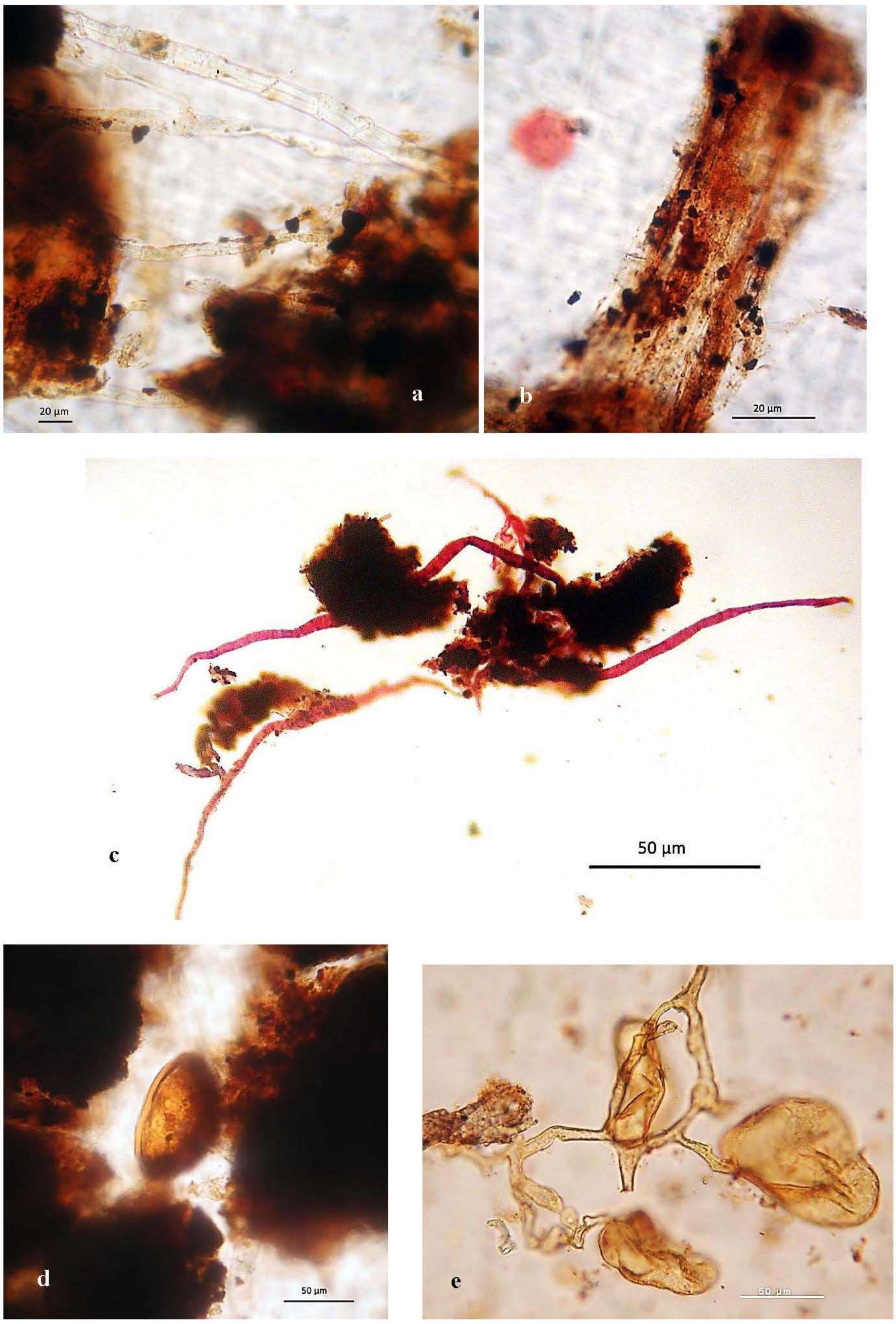


Figure 10. Organic matter, fibers, vessels, and mycorrhizal fungi a. Berrry-au-Bac le Vieux Tordoir st. 598 n°6 organic matter and fibers; b. detail of organic matter; c. Berry-au-Bac le Vieux Tordoir st. 598 n°1 organic matter and red sap-conducting vessels; d. Berry-au-Bac le Vieux Tordoir st. 598 n°7 organic matter and *Glomus* sp.; e. *Glomus* spores linked by their hyphae (mycelial filaments) (photos A. Emery-Barbier)

Archaeological context	Cultural attribution	Context	Tools type	Raw material	Tool's caracteristics	Use-wear
Remicourt En Bia Flo 2						
St. 251	LBK	detritic lateral pit	quern	quartzitic sandstone	massiv flat quern	cereals and secondary mineral grinding
St. 258	LBK	detritic lateral pit	quern	quartzitic sandstone	small quern	cereals grinding
Menneville Derrière le Village						
St. 617 M19 p7 n°3	LBK	enclosure ditch	grinder	quartzitic sandstone	bread-shaped ovoid grinder with flat active surface	animal grinding ?
Berry-au-Bac le Vieux Tordoir						
St. 598 n°1	LBK	grinding tool hoard in circular pit at the back of a house	quern	quartzitic sandstone	massiv large plano-concave quern	not possible to analyze (alteration)
St. 598 n°3	LBK	grinding tool hoard in circular pit at the back of a house	grinder	quartzitic sandstone	bread-shaped ovoid grinder ; low thickness	cereal grinding
St. 598 n°4	LBK	grinding tool hoard in circular pit at the back of a house	quern	quartzitic sandstone	large massiv quern with concav active surface	undetermined
St. 598 n°5	LBK	grinding tool hoard in circular pit at the back of a house	grinder	quartzitic sandstone	bread-shaped ovoid grinder ; low thickness and low degree of shaping	cereal grinding
St. 598 n°6	LBK	grinding tool hoard in circular pit at the back of a house	grinder	quartzitic sandstone	oblong grinder with low thickness, low degree of shaping, intense use	(wet) cereals grinding
St. 598 n°7	LBK	grinding tool hoard in circular pit at the back of a house	grinder	quartzitic sandstone	bread-shaped ovoid grinder with low thickness	cereal grinding

Str. 641	LBK	detritic lateral pit	grinder	quartzitic sandstone	bread-shaped ovoid grinder with low thickness	undetermined
Ath						
St. 12 Carre B3 (0-20)	LBK/ BVSG	detritic lateral pit	quern	quartzitic sandstone	quern on flat slab	cereal grinding
St. 12 B4 (20-40) Tool 1 n°40 bis	LBK/ BVSG	detritic lateral pit	quern	quartzitic sandstone	oblong grinder with low thickness, high degree of shaping, intense use	not possible to analyze (alteration)
St. 12 B4 (20-40) Tool 2 n°40 bis	LBK/ BVSG	detritic lateral pit	quern	quartzitic sandstone	oblong grinder with low thickness, low degree of shaping, intense use	(wet) cereals grinding
Loison sous Lens						
St. 11	BVSG	deposit of complete mill in lateral pit	quern	quartzitic sandstone	massiv concav quern with peripheral edge	(wet and well-cleaned) cereals grinding
St. 11 bloc	BVSG	deposit of complete mill in lateral pit	bloc	quartzitic sandstone	partial shaping	cereals grinding
St. 1008 NE p4	BVSG	deposit of complete mill in lateral pit	grinder	quartzitic sandstone	high degree of shaping	grinding of a humid matter, with mineral component
St. 1008 US2 p5	BVSG	deposit of complete mill in lateral pit	grinder	quartzitic sandstone	bread-shaped ovoid grinder with low thickness and plano-concav active surface	undetermined
St. 1038 decapage	BVSG	deposit of complete mill in lateral pit	grinder	quartzitic sandstone	quadrangular grinder	cereals grinding
St. 1074 decapage	BVSG	deposit of complete mill in lateral pit	grinder	quartzitic sandstone	quadrangular grinder	cereals grinding
St. 1119 SW	BVSG	deposit of complete mill in lateral pit	grinder	quartzitic sandstone	quadrangular grinder	(wet) cereals grinding
St. 1078	BVSG	deposit of complete mill in lateral pit	grinder	quartzitic sandstone	bread-shaped ovoid grinder with low thickness	undetermined
St. 1078 C1 p1	BVSG	deposit of complete mill in lateral pit	qu	quartzitic	reshaping and coarse pecking of the active surface	cereal grinding

			quern	sandstone		
Tremblay en France						
St. 110	BVSG	detritic lateral pit	grinder	quartzitic sandstone	grinder roughout	not used ?
ISO 15/16	BVSG	detritic lateral pit	quern	quartzitic sandstone	concav quern with peripheral edge	cereals?
ISO 408	BVSG	detritic lateral pit	quern	quartzitic sandstone	concav quern with circular grinding	undetermined
Verson						
St. 95 n°6517	BVSG	detritic lateral pit	grinder	conglometaric sandstone	plano-convex active surface	cereals grinding with strong stone against stone contact
St. 311/289 n°9188	BVSG	detritic lateral pit	grinder	granite	flat active surface	not possible to analyze (alteration)
St. 209 n°7490	BVSG	detritic lateral pit	grinder	quartzitic sandstone	granit, flat active surface	not possible to analyze (alteration)
St. 290, p3 n°9118	BVSG	detritic lateral pit	grinder	granite	granit, flat active surface	not possible to analyze (alteration)
Aubechies Coron Maton						
St. 405	BVSG	detritic lateral pit	grinder	quartzitic sandstone	bread-shaped ovoid grinder with low thickness	not possible to analyze (alteration)
Choisy-au-Bac						
St. 120 256 n° 3848	Cerny	detritic level	quern	quartzitic sandstone	narrow oblong quern with circular grinding active surface	soft matter grinding, wet, vegetal (other than cereal) or animal
Zone 4 surface level n° 3174	Cerny	detritic level	quern	quartzitic sandstone	narrow oblong quern with circular grinding active surface	(wet) cereals grinding

Table 1. Results: main morphological, technological, and use-wear characteristics of the querns and grinders analyzed

Archaeological context	**Tool type**	**Comparative sediment y/n**	**Comparative sediment comments**	***Triticum* sp. (wheat)**	***T. dicoccum* (emmer wheat)**	***Hordeum* sp. (barley)**	***Cerealia***	**cf. *Avena* sp. (oat)**	**Fabaceae family**	***Pisum* sp. (pea)**	**Paniceae tribe (ex. *Setaria* sp.)**	**Underground storage organs**	**Unidentified**	**Damaged**	**Comments**
Remicourt	**LBK**														
St. 251	quern	n					1				4		2	3	Starch masses
St. 258	quern	n					2				1	3	6	14	
Menneville	**LBK**														
St. 617 M19 p7 n°3	grinder	y									1	2	3	3	
BVT	**LBK**														
St. 598 n°1	quern	y					1			1	1	1	4	1	Starch masses
St. 598 n°3	grinder	y	few, very damaged phytoliths	3			1					1	2	2	Starch masses
St. 598 n°4	quern	y	few, very	1 (+cluster)			1					2	1	2	Starch masses

			damaged phytoliths												
St. 598 n°5	grinder	y		3		1	4				3 (+cluster)		2	2	Yellow masses, numerous crystals, evidence of sprouted grains
St. 598 n°6	grinder	y		9 (+clusters)			3				1		4	7	
St. 598 n°7	grinder	y	fibres	1			2					5	3	1	Amyloplasts
Str. 641	grinder	y	fibres				2						1	2	Starch masses
Ath	**BVSG**														
St. 12 Carre B3 (0-20)	quern	n					4 (+1 cluster)						1		Starch masses
St. 12 B4 (20-40) Tool 1 n°40 bis	quern	n		11		3	47		1			1	10	9	Evidence of sprouted grains
St. 12 B4 (20-40) Tool 2 n°40 bis	quern	n					4	1	(1 cluster)			2	8	4	Starch masses, blue fiber, fatty layer on active surface
Loison sous Lens	**BVSG**														
St. 11	quern	n		1			2						1		Starch masses
St. 11 Bloc	bloc	n		1		5 (+1 cluster)	1						2	2	Starch masses
St. 1008 NE p4	grinder	n		2			1					2	1	4	Starch mass probably belonging to wild plants (ex.

															Polygonaceae, Poaceae, Cyperaceae). Lots of cooked/damaged starch grains
St. 1038 surface cleaning	grinder	n												1	Starch masses
St. 1074 surface cleaning	grinder	y	fibres	1			3				5			1	Starch masses
St. 1119 SW	grinder	n		2		1	5					2	2	3	Starch masses, cooked tubers
Tremblay en France	**BVSG**														
St. 110	grinder	y			(1 cluster)		1						3	4	
ISO 15/16	quern	n					(1 cluster)					2	2		Starch masses
ISO 408	quern	y	fibres											1	Starch masses
Verson	**BVSG**														
St. 95 n°6517	grinder	n		3(+1 cluster)			10		1	2	5	3	4	10	Starch masses, evidence of sprouted grains
St. 311/289 n°9188	grinder	y		1			2(+6 clusters)							3	Starch masses
St. 209 n°7490	grinder	y		1			3						1	3	

St. 290, p3 n°9118	grinder	y		1			4				1		2		
Aubechies	**BVSG**														
St. 405	grinder	n		1										1	Fibers?
Choisy	**Cerny**														
St. 120 256 n° 3848	quern	y	fibres								2				Amyloplasts, crystals
Zone 4 surface cleaning n° 3174	quern	y		1		1	5			1	3		2	3	Starch masses

Table 2. Results of starch grain analysis

CONTEXT	**TOOL**		**SEDIMENT**	
	Frequency	**Vessels + Fibers**	**Frequency**	**Vessels + fibers**
Tremblay-en-France St. 110	***	red vessels, in connection with masses of organic matter, presence of raphides	***	one punctuated vessel and numerous white fibers
Tremblay-en-France ISO 408	*	red vessels, in connection with masses of organic matter, presence of raphides	**	white fibers
Menneville St. 617 M19 p7 n°3	**	white tapered fibers	o	
Berry-au-Bac St. 598 n°1	****	red vessels	**	sharp, short fibers no organic matter present
Berry-au-Bac St. 598 n°3	*	white tapered fibers		
Berry-au-Bac St. 598 n°4	****	red and brown sap conducting vessels *Urtica dioica* leaf epidermis		
Berry-au-Bac St. 598 n°5	*	red vessels		

Berry-au-Bac St. 598 n°6	****	long and large vessels		
Berry-au-Bac St. 598 n°7	**	some tapered fibers		
Berry-au-Bac St. 641	****	red vessels		

Table 3. Results of phytolith and Non-Pollen Palynomorphs analysis

Archaeological contexts	Tools types		Phytoliths morphotypes / Anatomical origin and taxonomic value		Poaceae culms/leaves	rondel / poaceae-pooideae but other subfamilies	poaceae epidermis / elongate and narrow long cells	elongate / low value	elongate sinuate / poaceae leaf epidermis, cyperaceae, ferns	elongate triangular section	elongate sinuate with concave ends / phragmites?	bulliform flabellate / poaceae, cyperaceae leaves epidermis	rectangular psilate	rectangular castellate	rectangular dentate	rectangular granulate	rectangular sinuate	trapezoid / many pooideae grasses	polylobate / mainly in Panicoideae leaves & inflor	bilobate	trilobate / mainly in Panicoideae leaves & inflo	Poaceae inflorescences
Remicourt En Bia Flo 2	**LBK**																					
St. 251	quern																					
St. 258	quern																					
Menneville Derrière le Village	**LBK**																					
St. 617 M19 p7 n°3	grinder	AF											12		3			1				
		RF																				
Berry-au-Bac le Vieux Tordoir	**LBK**																					
St. 598 n°1	quern	AF																				
		RF																				
St. 598 n°3	grinder	AF					1	2				2	7									
		RF																				
St. 598 n°4	quern	AF																				
		RF																				
St. 598 n°5	grinder	AF											1									
		RF																				
St. 598 n°6	grinder	AF																				
		RF																				
St. 598 n°7	grinder	AF				1		6		1			17									
		RF																				
Str. 641	grinder	AF											5		1							
		RF																				
Ath	**LBK/BVSG**																					
St. 12 Carre B3 (0-20)	quern	AF				16		56		1		3	66		2			7	1			
		RF				7		24		0,4		1,3	29		0,9			3	0,4			
St. 12 B4 (20-40) Tool1 n°40 bis	quern	AF				4		50		12			29	1	1			5	1	4	2	
		RF				2		26		6			15	0,5	0,5			2,5	0,5	2	1	
St. 12 B4 (20-40) Tool2 n°40 bis	quern	AF				2		19				8	50		4	1	3	2				
		RF				1,2		12				4,8	30		2,4	0,6	1,8	1,2				
Loison sous Lens	**BVSG**																					
St. 11	quern	AF						8				1						1				
		RF																				
St. 11 bloc	bloc	AF						12										4				
		RF																				
St. 1008 NE p4	grinder	AF																				
St. 1008 US2 p5	grinder	AF						10				3						8				
		RF																				
St. 1074 decapage	grinder	AF						13										3				
		RF																				
St. 1078	grinder	AF						32										6				
		RF																				
St. 1078 C1 pl	quern	AF						1										1				
		RF																				
Tremblay en France	**BVSG**																					
St. 110	grinder	AF				2	26	60					36					4		1		
		RF				1	12,7	29,4					17,6					2		0,5		
ISO 15/16	quern	AF						13								12						
ISO 408	quern	AF				4	6	39	1			3				39		10	5			
		RF				2	3	20	0,5			1,5				20		5,15	2,5			
Verson	**BVSG**																					
St. 95 n° 6517	grinder	AF				7	10	8					31	5	8	14		8				
		RF				4,3	6,2	5					19	3	5	8,7		5				
St. 311/289 n°9188	grinder	AF				3	6	62				1	9		2							
		RF				2,2	4,5	47				0,75	6,8		1,5							
St. 209 n°7490	grinder	AF				3	1	29	1		1		27						6			
		RF				2,4	0,8	23,4	0,8		0,8		21,8						4,8			
St. 290, p3 n°9118	grinder	AF				3	15	32				1	71						1			
		RF				1,6	8	17,2				0,53	38,2						0,53			
Aubechies Coron Maton	**BVSG**																					
St. 405	grinder																					
Choisy-au-Bac	**Cerny**																					
St. 120 256 n° 3848	quern	AF					1						14									
		RF																				
Zone 4 surface level n° 3174	quern	AF																				
		RF																				

Archaeological contexts	Tools types		elongate echinate/dentate / bracts inflorescences	elongate dendritic / epidermis of inflorescences bracts	dendritic fragments	trapezoid base sinuate / lamina tissue	silicified articulated cells / epidermis of inflorescences bracts	Acute bulbosus / used as a diagnostic of grasses	Tracheary	tracheary annulate / leaves and herbaceous stems and roots	Dicotyledons	fusiform	oblong	ovate	prismatic polyhedral	epidermis	Woody dicotyledons	blocky / bark wood parenchyma low value	blocky irregular / bark wood parenchyma cork	cork cell / bark
Remicourt En Bia Flo 2	**LBK**																			
St. 251	quern																			
St. 258	quern																			
Menneville Derrière le Village	**LBK**																			
St. 617 M19 p7 n°3	grinder	AF					1	1	1											
		RF																		
Berry-au-Bac le Vieux Tordoir	**LBK**																			
St. 598 n°1	quern	AF					1													
		RF																		
St. 598 n°3	grinder	AF						1												
		RF																		
St. 598 n°4	quern	AF						1												
		RF																		
St. 598 n°5	grinder	AF																		
		RF																		
St. 598 n°6	grinder	AF						2												
		RF																		
St. 598 n°7	grinder	AF			3			5										1		
		RF																		
Str. 641	grinder	AF																		
		RF																		
Ath	**LBK/BVSG**																			
St. 12 Carre B3 (0-20)	quern	AF	8	8		9		4						6				30		
		RF	3,5	3,5		4		1,7						2,6				13		
St. 12 B4 (20-40) Tool1 n°40 bis	quern	AF		21	16	4	1	40						4						
		RF		10,5	8	2	0,5	20						2						
St. 12 B4 (20-40) Tool2 n°40 bis	quern	AF	3	3				27	1			10			6			10		
		RF	1,8	1,8				16	0,6			6			3,6			6		
Loison sous Lens	**BVSG**																			
St. 11	quern	AF						1												2
		RF																		
St. 11 bloc	bloc	AF		3				1												
		RF																		
St. 1008 NE p4	grinder	AF																		
St. 1008 US2 p5	grinder	AF		1				2								3				13
		RF																		
St. 1074 decapage	grinder	AF		1				4												6
		RF																		
St. 1078	grinder	AF		4				2												4
		RF																		
St. 1078 C1 pl	quern	AF																		
		RF																		
Tremblay en France	**BVSG**																			
St. 110	grinder	AF	8	8				27					2							
		RF	4	4				13,2					1							
ISO 15/16	quern	AF		1				5	2					1				8		
ISO 408	quern	AF	5	10		11		19		1		7	2					3	2	
		RF	2,5	5,2		5,6		9,8		0,5		3,6	1					1,5	1	
Verson	**BVSG**																			
St. 95 n° 6517	grinder	AF	3	31		12	1	1				1			2			10		
		RF	1,8	19,3		7,5	0,6	0,6				0,6			1,2			6,2		
St. 311/289 n°9188	grinder	AF	13	5		1		8				1						7		
		RF	9,8	3,8		0,8		6				0,8						5,3		
St. 209 n°7490	grinder	AF	12	13		3		11										2	1	
		RF	9,6	10,4		2,4		8,8										1,6	0,8	
St. 290, p3 n°9118	grinder	AF	14	10		4		12										8	2	
		RF	7,5	5,3		2,1		6,4										4,3	1	
Aubechies Coron Maton	**BVSG**																			
St. 405	grinder																			
Choisy-au-Bac	**Cerny**																			
St. 120 256 n° 3848	quern	AF								9								2		
		RF																		
Zone 4 surface level n° 3174	quern	AF																		
		RF																		

Archaeological contexts	Tools types		elongate with globular parts / bark	elongate facetate / bark	cylindric geniculate psilate / sclereid of woody dicotyledons	sclereid / bark	spheroid decorated / wood	Weathered	Indetermined	TOTAL PHYTOLITHS	Plant residue	Pollen	Spores	Pteridophytes	Glomus sp	Fungi	Fibres	Sponge spicules-Diatoms
Remicourt En Bia Flo 2	**LBK**																	
St. 251	quern																	
St. 258	quern																	
Menneville Derrière le Village	**LBK**																	
St. 617 M19 p7 n°3	grinder	AF					1			20	****				3	6	**	****
		RF																
Berry-au-Bac le Vieux Tordoir	**LBK**																	
St. 598 n°1	quern	AF								1					15		****	
		RF																
St. 598 n°3	grinder	AF						4		13				14	23	7	****	
		RF																
St. 598 n°4	quern	AF						1				****	21	2	21		****	1
		RF																
St. 598 n°5	grinder	AF						1		1	****						*	1
		RF																
St. 598 n°6	grinder	AF								2					3	2	****	5
		RF																
St. 598 n°7	grinder	AF						4		38	****						**	12
		RF																
Str. 641	grinder	AF						6									****	
		RF																
Ath	**LBK/BVSG**																	
St. 12 Carre B3 (0-20)	quern	AF			12					229								25
		RF			5,2													
St. 12 B4 (20-40) Tool1 n°40 bis	quern	AF					1			196	**							
		RF					0,5											
St. 12 B4 (20-40) Tool2 n°40 bis	quern	AF						16		165				8				1
		RF						9,7										
Loison sous Lens	**BVSG**																	
St. 11	quern	AF					2			15								
		RF																
St. 11 bloc	bloc	AF				8				28								
		RF																
St. 1008 NE p4	grinder	AF																
St. 1008 US2 p5	grinder	AF					16			56								
		RF																
St. 1074 decapage	grinder	AF				1				28								
		RF																
St. 1078	grinder	AF				2				50								
		RF																
St. 1078 C1 pl	quern	AF								2								
		RF																
Tremblay en France	**BVSG**																	
St. 110	grinder	AF	10	1			3	11	5	229		2		6		***		11
		RF	5	0,5			1,5	5,4	2,4									
ISO 15/16	quern	AF							5	47					**		****	
ISO 408	quern	AF						19	8	230						*		4
		RF						9,8	4,1									
Verson	**BVSG**																	
St. 95 n° 6517	grinder	AF						8		160				3			53	16
		RF						5										
St. 311/289 n°9188	grinder	AF						14		132							30	17
		RF						10,6										
St. 209 n°7490	grinder	AF				1	1	12		196							****	14
		RF				0,8	0,8	9,6										
St. 290, p3 n°9118	grinder	AF						13		186							*	3
		RF						7										
Aubechies Coron Maton	**BVSG**																	
St. 405	grinder																	
Choisy-au-Bac	**Cerny**																	
St. 120 256 n° 3848	quern	AF						26			****	4					****	
		RF																
Zone 4 surface level n° 3174	quern	AF								3		3					****	
		RF																

Table 4. Comparison of fiber composition in tool residues and surrounding sediments

	Use-wear	Starch grains	Phytoliths
Cereals	***	***	*
Legumes	++	***	o
Underground Storage Organs	+	***	o
Nuts	**	*	?
Wild plants	o	*	o
Ferns	o	o	***
Urticae	o	o	*
Grinding	***	***	*
Dehusking	++	*	*
Humidification	*	o	*
Heating	*	***	o
Sprouting	o	***	o
Specialisation	*	*	*
Multifunctionality	***	***	***

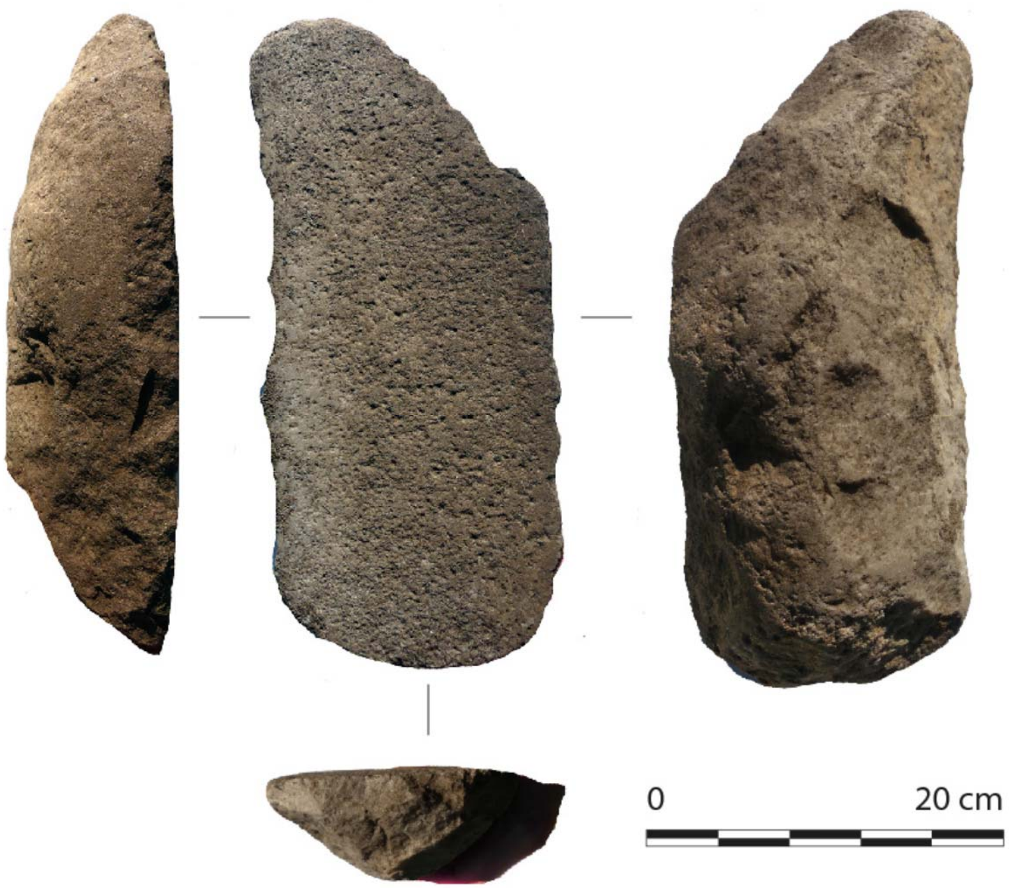
Table 5. Level of information provided by each type of analysis o: no information, + poorly informative, +++ highly informative

Archaeological context	Tools type	Use-wear	Starch grains	Phytoliths
Remicourt En Bia Flo 2	**LBK**			
St. 251	quern	cereals and secondary mineral grinding	Cereal, wild plants, starch masses	not tested ; not enough sediment
St. 258	quern	cereals grinding	Cereal, wild plants, USO	not tested ; not enough sediment
Menneville Derrière le Village	**LBK**			
St. 617 M19 p7 n°3	grinder	animal grinding?	Wild plants, USO	sterile
Berry-au-Bac le Vieux Tordoir	**LBK**			
St. 598 n°1	quern	not possible to analyze (alteration)	Cereal, Fabaceae, wild plants, USO, starch masses	fibers
St. 598 n°3	grinder	cereal grinding	Cereal, USO, starch masses	fibers; plant residue
St. 598 n°4	quern	undetermined	Cereal, USO, starch masses	fibers
St. 598 n°5	grinder	cereal grinding	Cereal, wild plants, starch masses	fibers
St. 598 n°6	grinder	(wet) cereals grinding	Cereal, wild plants	fibers
St. 598 n°7	grinder	cereal grinding	Cereal, USO, starch masses	fibers
Str. 641	grinder	undetermined	Cereal, starch masses	fibers
Ath	**BVSG**			
St. 12 Carre B3 (0-20)	quern	cereal grinding	Cereal, starch masses	Cereals - bark
St. 12 B4 (20-40) Tool 1 n°40 bis	quern	not possible to analyze (alteration)	Cereal, Fabaceae, USO	Cereals
St. 12 B4 (20-40) Tool 2 n°40 bis	quern	(wet) cereals grinding	Cereal, Fabaceae, USO, starch masses	Cereals - wood
Loison sous Lens	**BVSG**			
St. 11	quern	(wet and well-cleaned) cereals grinding	Cereal, starch masses	sterile
St. 11 bloc	bloc	cereals grinding	Cereal, starch masses	Cereals - bark
St. 1008 NE p4	grinder	grinding of a humid matter, with mineral component	Cereal, USO, starch masses	sterile
St. 1008 US2 p5	grinder	undetermined	not tested	wood - bark (few phytoliths)
St. 1038 decapage	grinder	cereals grinding	Cereal, starch masses	not tested; not enough sediment
St. 1074 decapage	grinder	cereals grinding	Cereal, wild plants, starch masses	bark (few phytoliths)
St. 1119 SW	grinder	(wet) cereals grinding	Cereal, USO, starch masses	not tested ; not enough sediment
St. 1078	grinder	undetermined	not tested	Cereals - bark
St. 1078 C1 p1	quern	cereal grinding	not tested	sterile
Tremblay en France	**BVSG**			
St. 110	grinder	not used ?	Cereal	Cereals - bark
ISO 15/16	quern	cereals?	Cereal, USO, starch masses	fibers
ISO 408	quern	undetermined	Starch masses	Cereals - wood
Verson	**BVSG**			
St. 95 n°6517	grinder	cereals grinding with strong stone against stone contact	Cereal, Fabaceae, wild plants, USO, starch masses	Cereals - wood/ bark
St. 311/289 n°9188	grinder	not possible to analyze (alteration)	Cereal	Cereals - wood/bark
St. 209 n°7490	grinder	not possible to analyze (alteration)	Cereal	Cereals - wood/bark
St. 290, p3 n°9118	grinder	not possible to analyze (alteration)	Cereal, wild plants, starch masses	Cereals - wood/bark
Aubechies Coron Maton	**BVSG**			
St. 405	grinder	undetermined	Cereal	not tested
Choisy-au-Bac	**Cerny**			
St. 120 256 n° 3848	quern	inding ; soft matter grinding, wet, vegetal (other than cereal)	Wild plants, starch masses	fibers - plant residue
Zone 4 surface level n° 3174	quern	circular grinding ; (wet) cereals grinding	Cereal, Fabaceae, wild plants, starch masses	fibers

Table 6. Combined results of use-wear, starch grains, and phytoliths and Non-Pollen Palynomorphs analysis

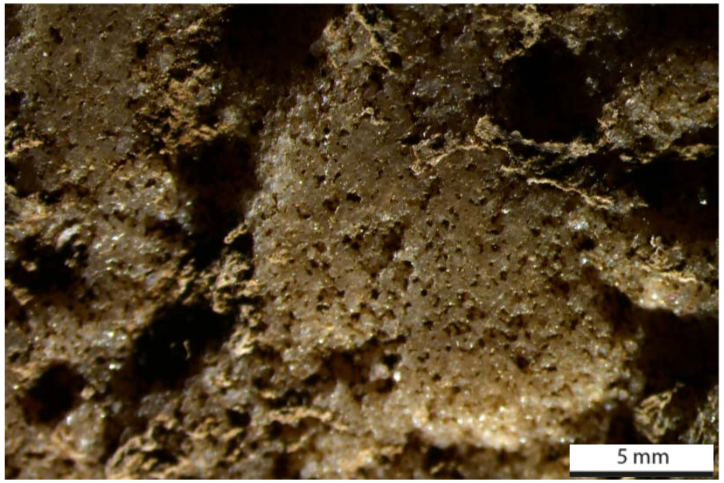
Berry-au-Bac le Vieux Tordoir st. 598 n°6

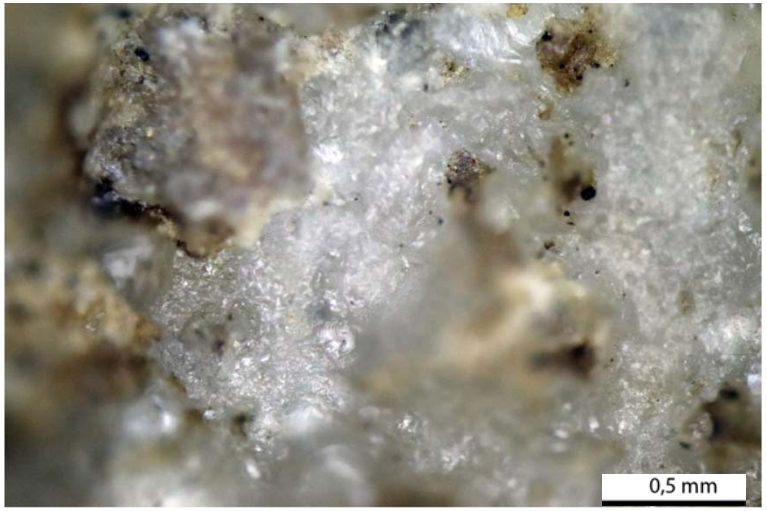
TOOL

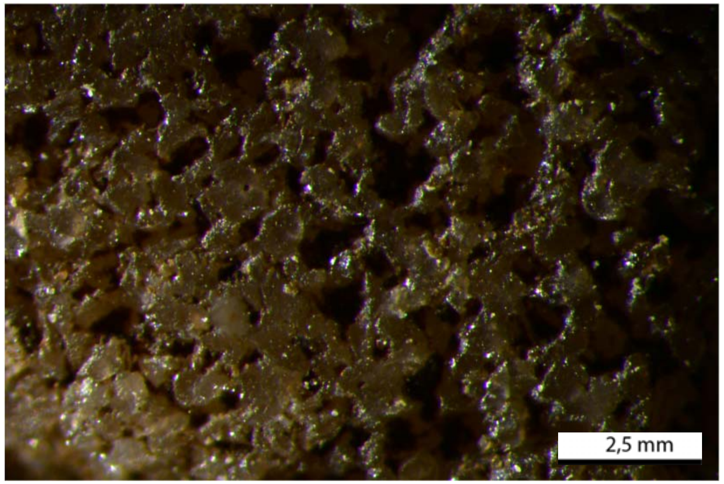


Berry-au-Bac le Vieux Tordoir st. 598 n°6

USE-WEAR TRACES



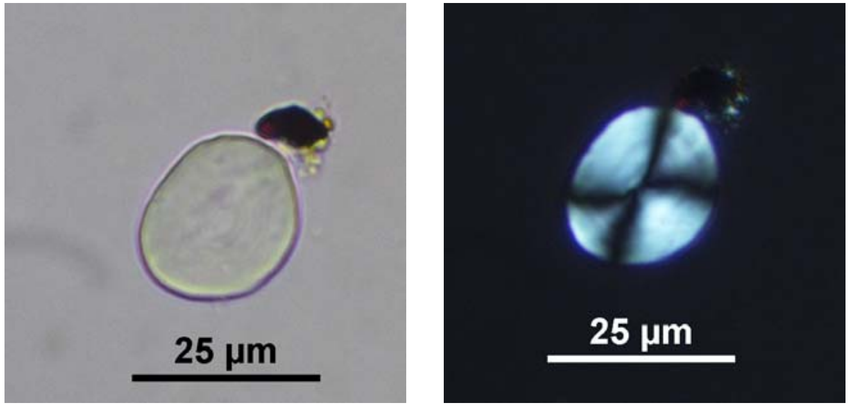




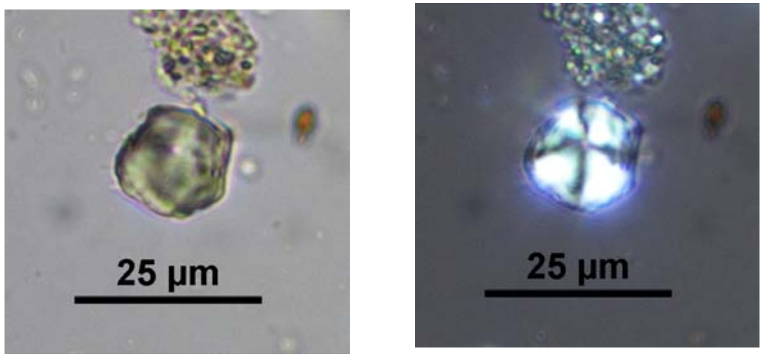
X5 et x50 : strong levelling in plateau, strong grain rounding, and well-developed smoothing characteristic of cereal grinding, x200: micropitted and irregular reflexive micropolish that suggest on the contrary the processing of abrasive fine particles

Berry-au-Bac le Vieux Tordoir st. 598 n°6

STARCH GRAINS



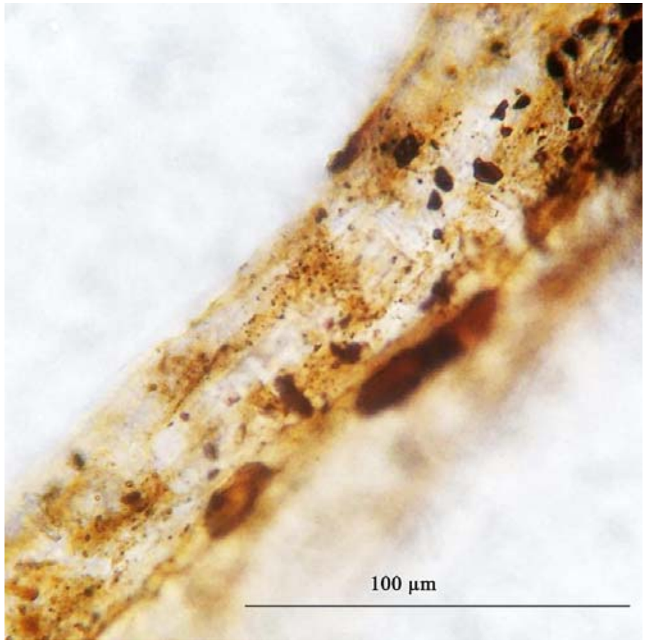
Cerealia

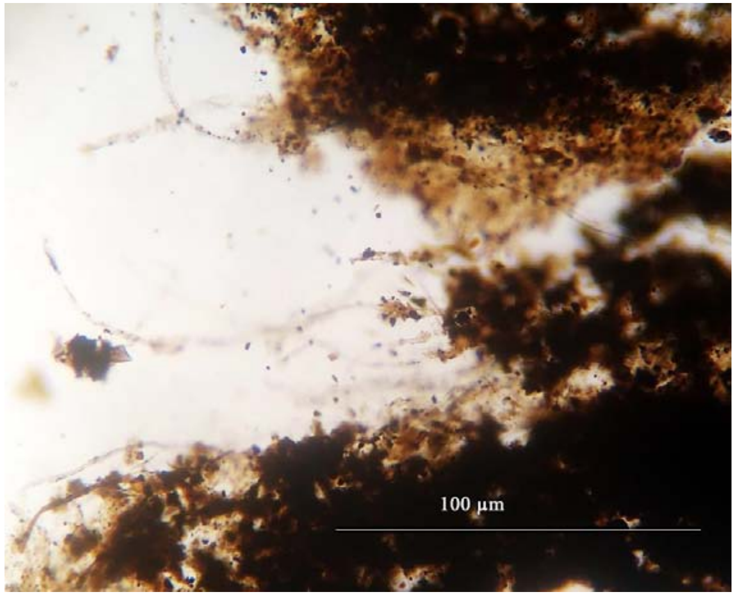


Setaria sp.

Berry-au-Bac le Vieux Tordoir st. 598 n°6

PHYTOLITHS





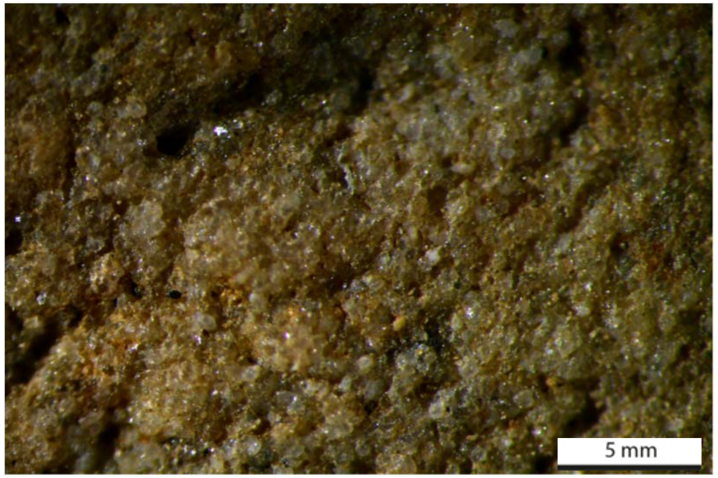
Plants residues and fibers

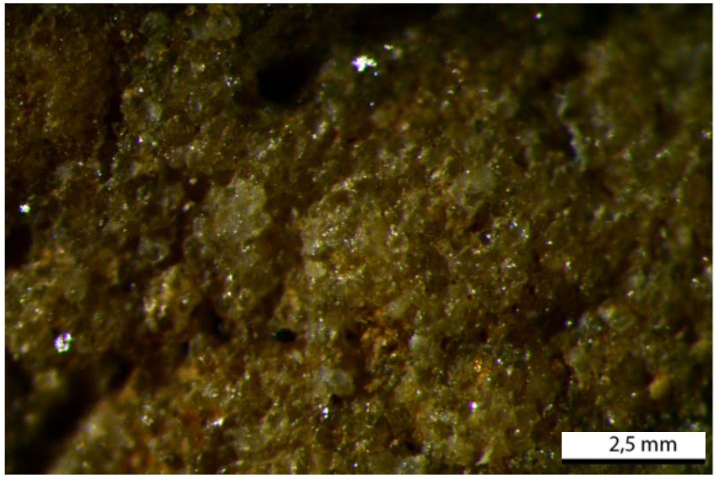
Ath st. 12 carré B3

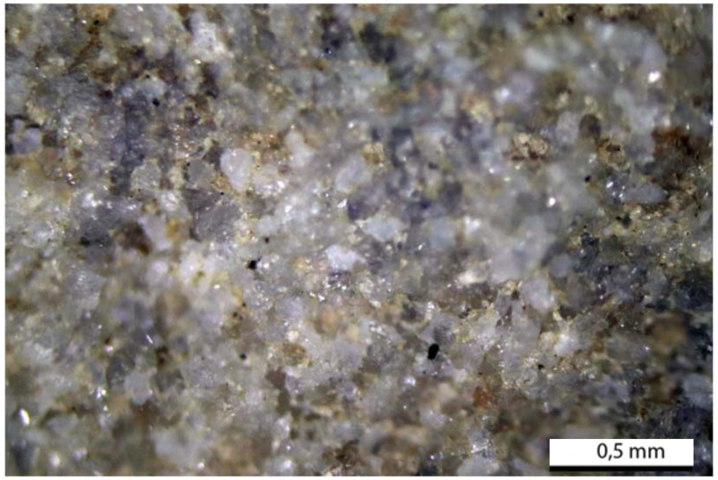
TOOL

Ath st. 12 carré B3

USE-WEAR TRACES



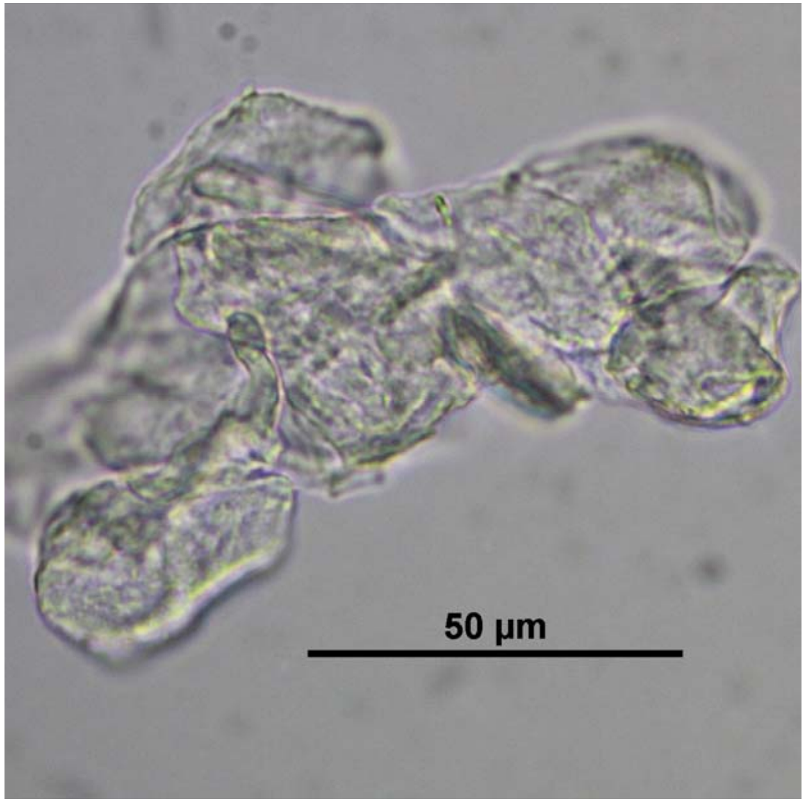




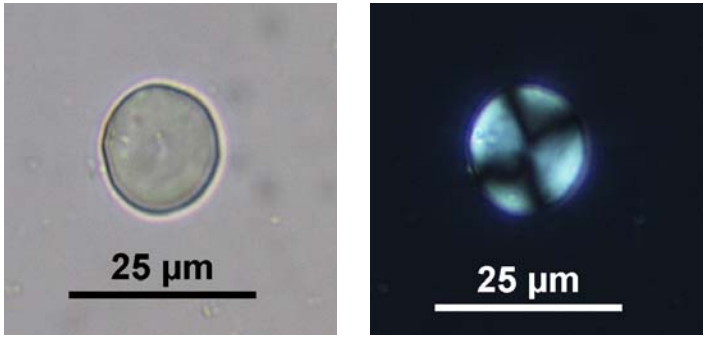
X5 et x50 : levelling of the high parts of the microrelief, grain rounding, and smoothing characteristic of cereal grinding,
x200: grain rounding

Ath st. 12 carré B3

STARCH GRAINS



Starch mass



Cerealia

Ath st. 12 carré B3

PHYTOLITHS and ANIMAL MICRO-FOSSIL

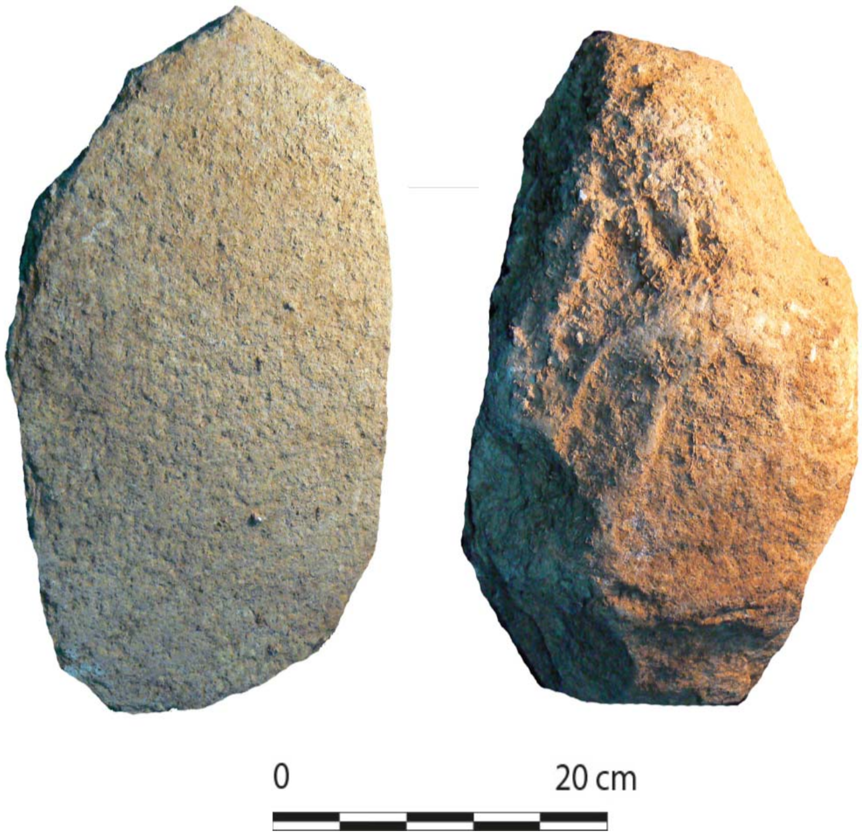
Elongate dendritic fragment

Paralellepipedal-trapezoid and elongate

Sponge spicule

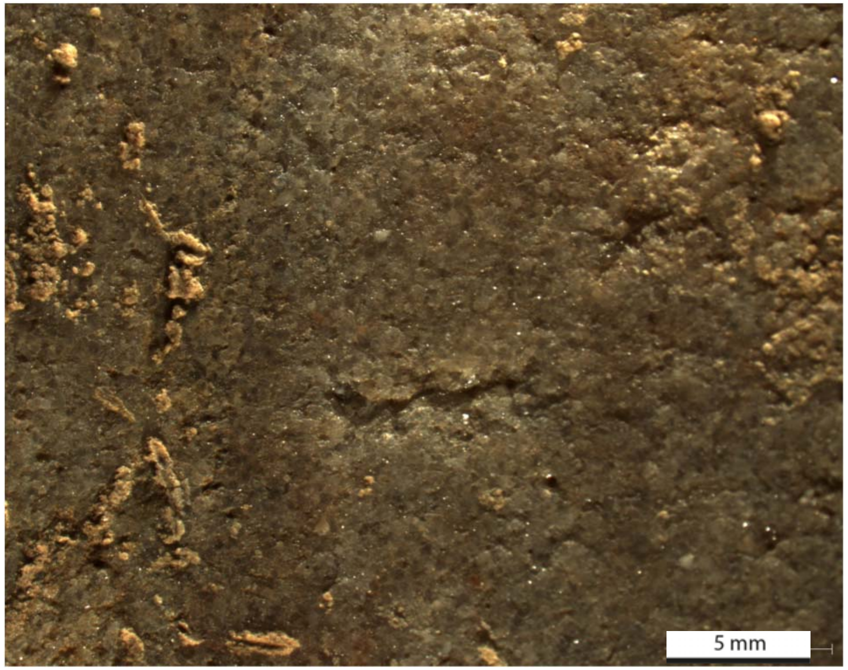
Loison-sous-Lens st. 1008 NE p4

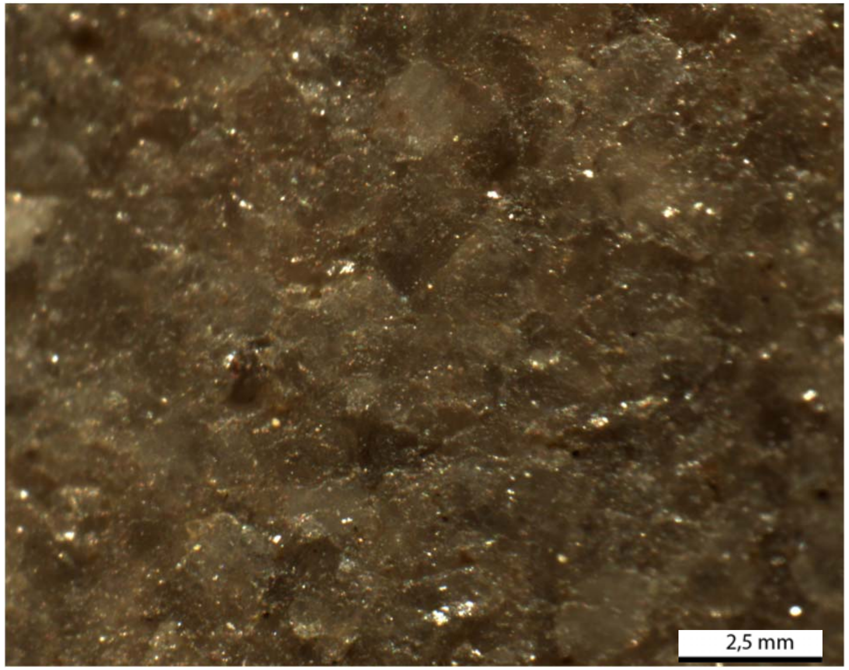
TOOL



Loison-sous-Lens st. 1008 NE p4

USE-WEAR TRACES

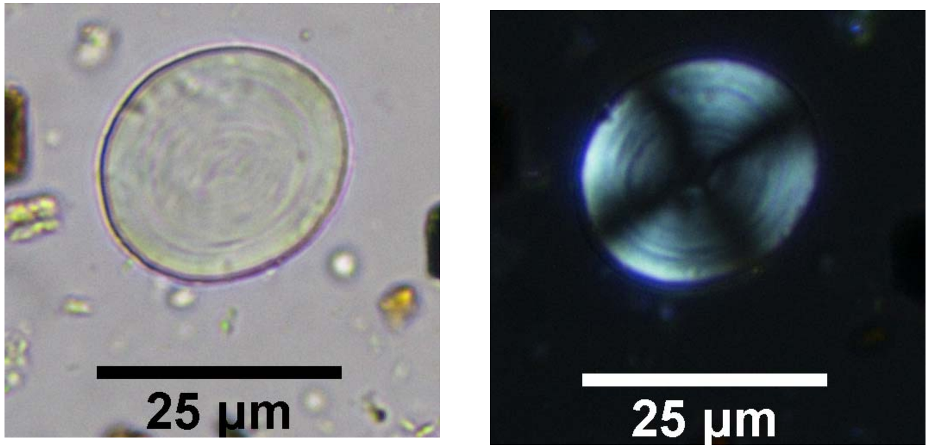




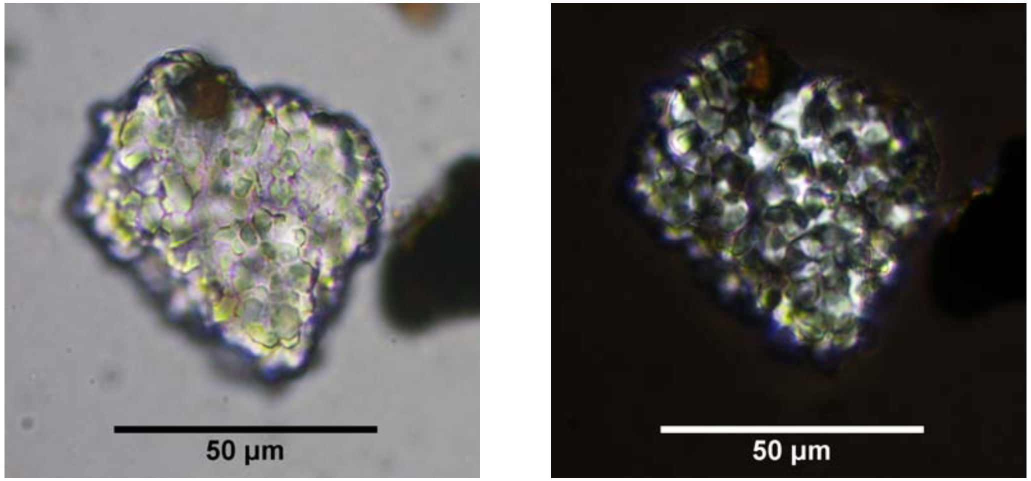
X5 et x50 : strong levelling in plateau, strong grain rounding, and well-developed smoothing characteristic of cereal grinding,

Loison-sous-Lens st. 1008 NE p4

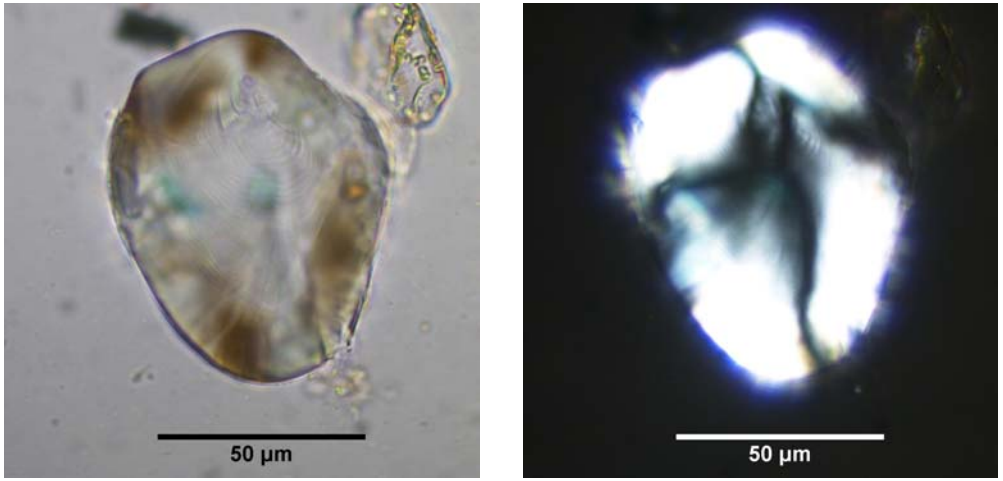
STARCH GRAINS



Wheat



Starch mass

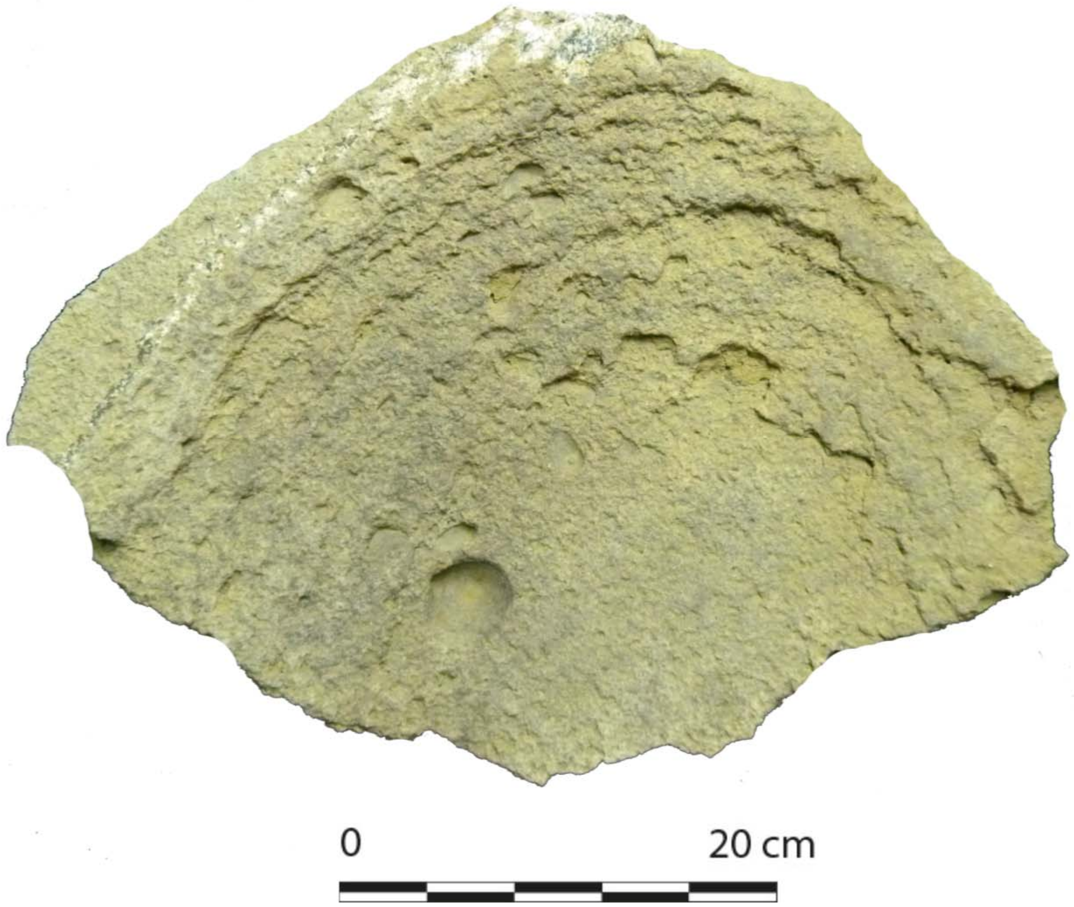


USO

No phytoliths

Tremblay en France ISO 408

TOOL



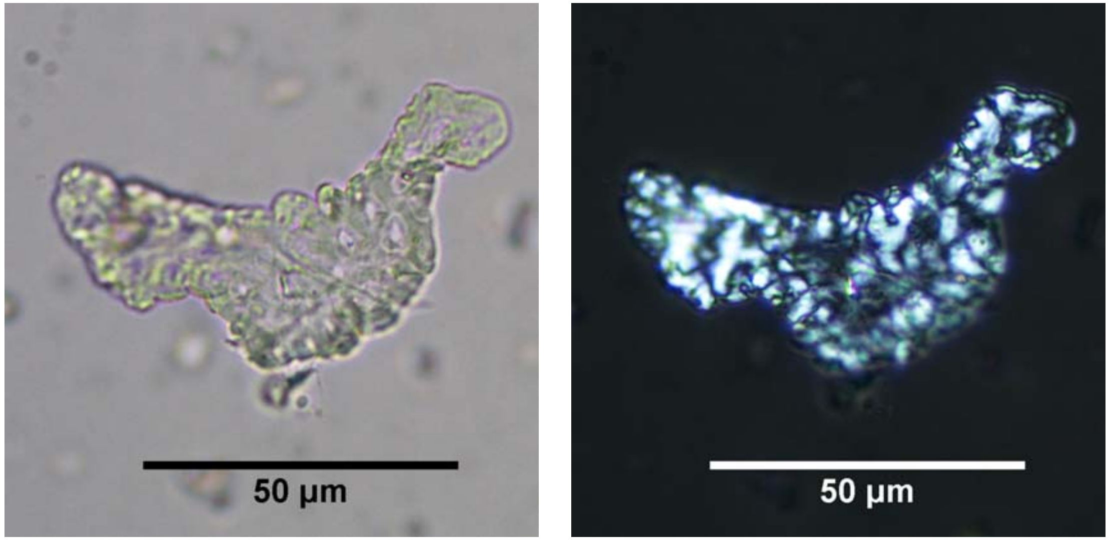
Tremblay en France ISO 408

USE-WEAR TRACES

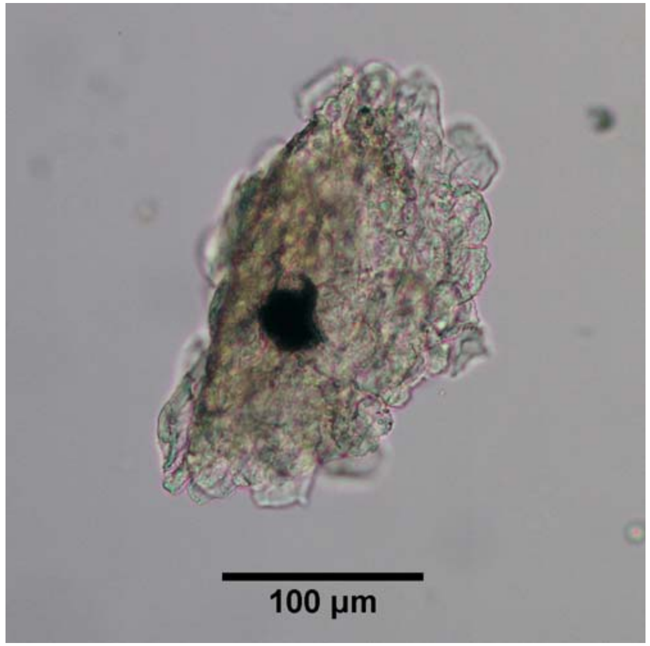
- Badly preserved use-wear traces

Tremblay en France ISO 408

STARCH GRAINS



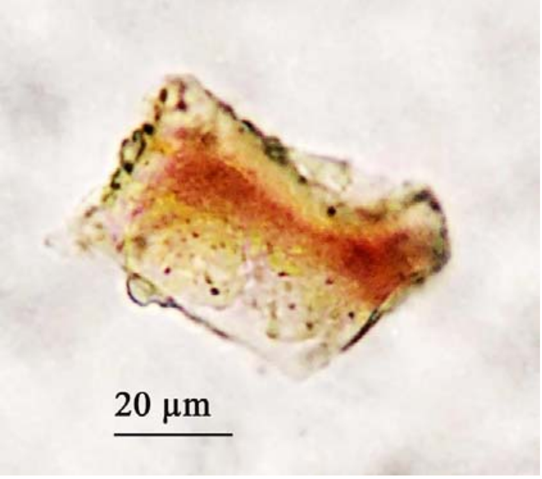
Starch mass



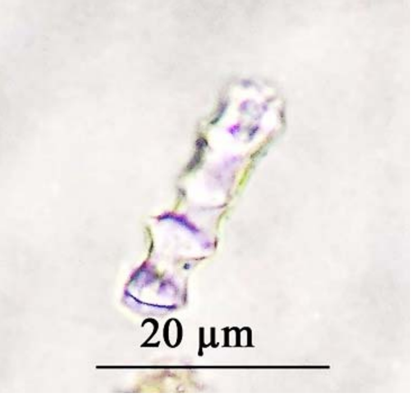
Starch mass (no cross-polarized photo)

Tremblay-en-France ISO 408

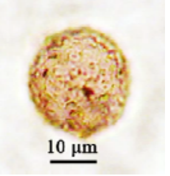
PHYTOLITHS



Blocky



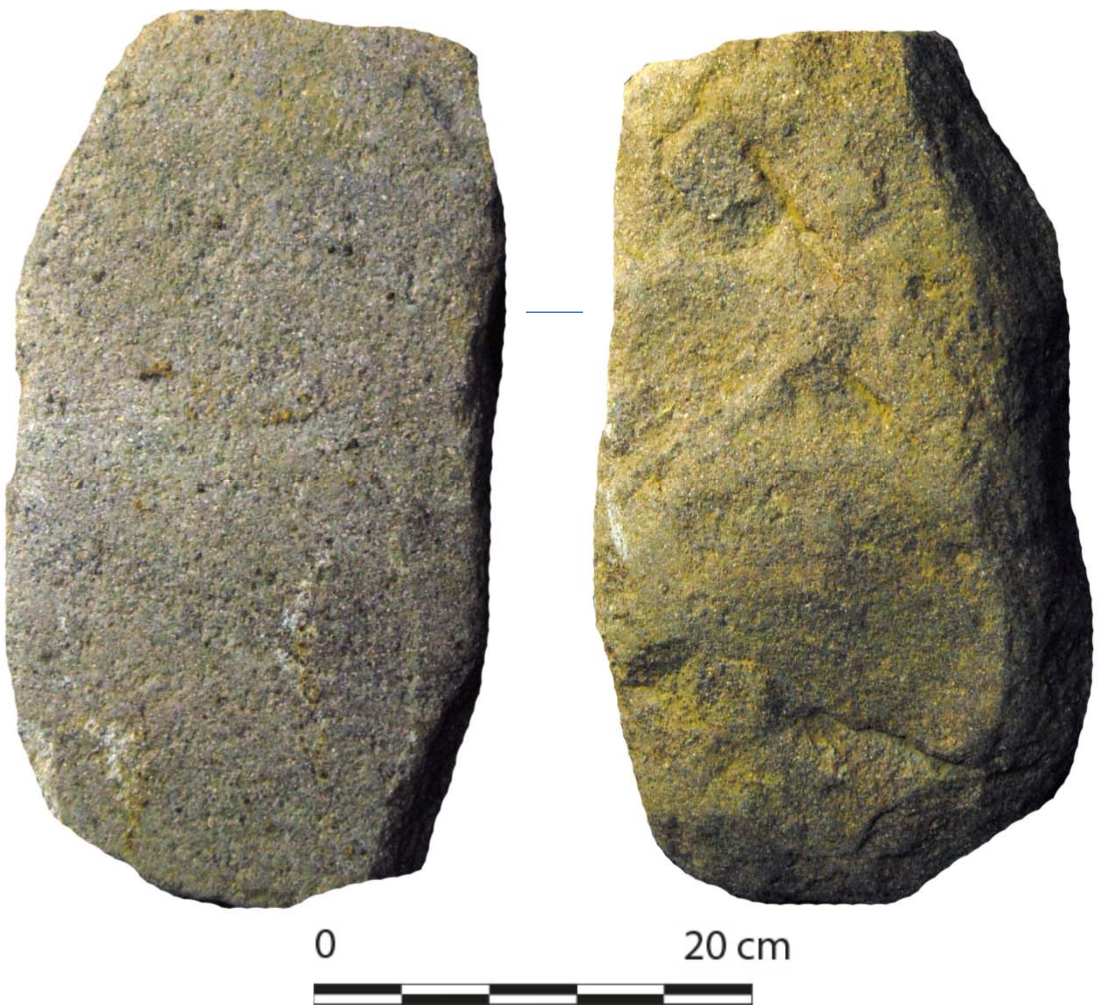
Weathered elongate dendritic



Spheroid decorate

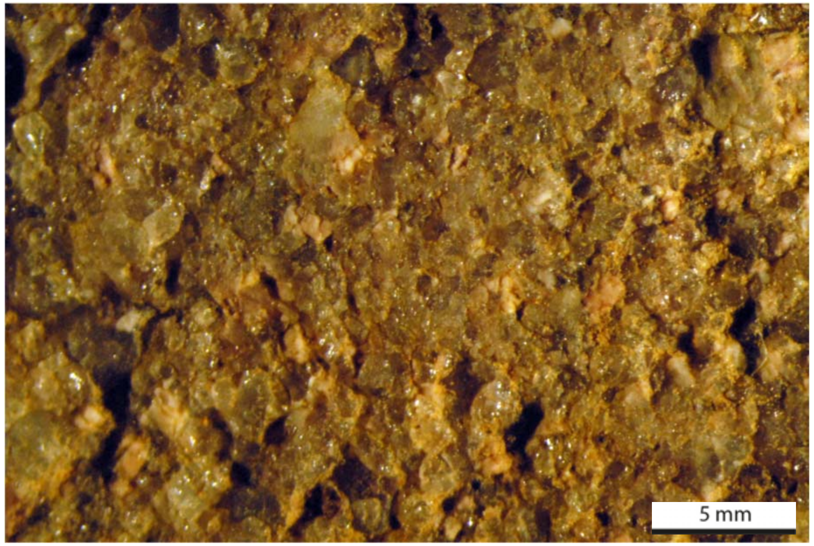
Verson st 95 n°6517

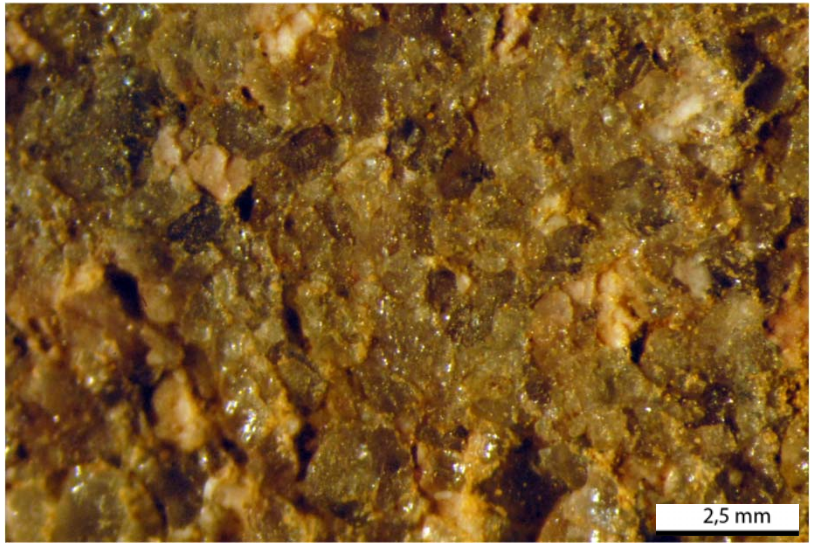
TOOL



Verson st 95 n°6517

USE-WEAR TRACES

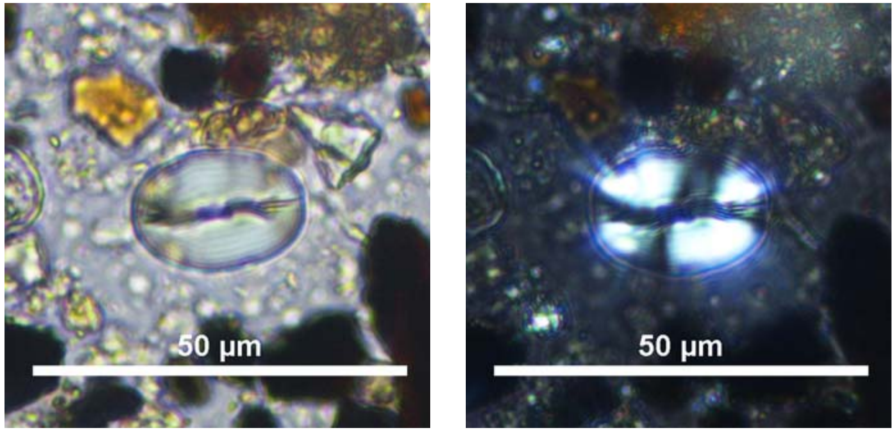




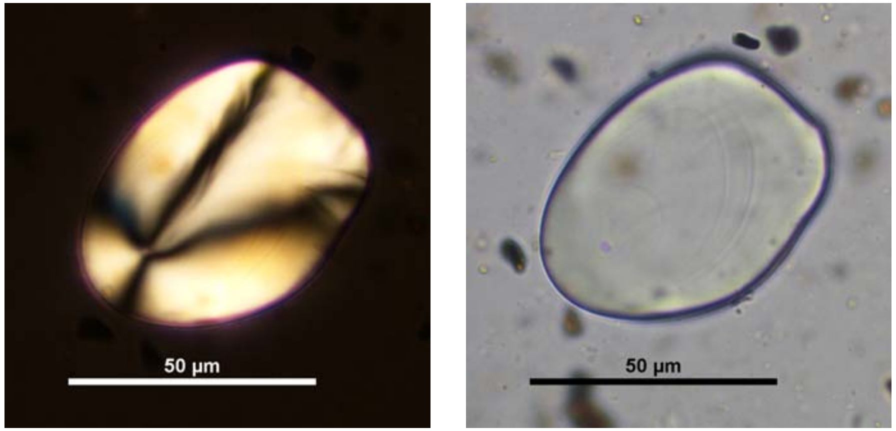
X5 et x50 : strong levelling in plateau, strong grain rounding, and well-developed smoothing characteristic of cereal grinding ; microfractures of grains linked to strong stone against stone contact.

Verson st 95 n°6517

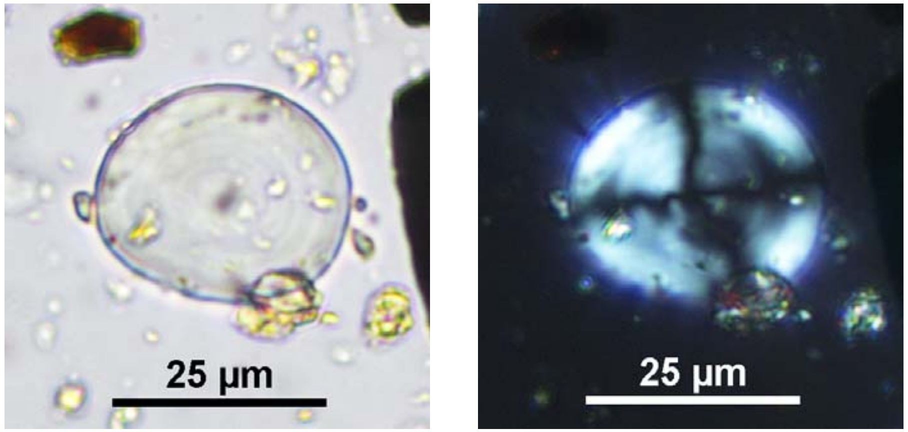
STARCH GRAINS



Fabaceae (cf. *Pisum* sp.)



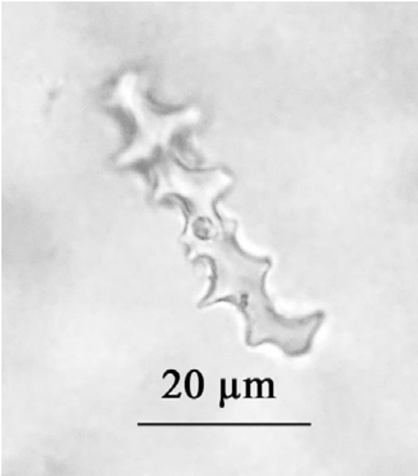
Underground storage organ



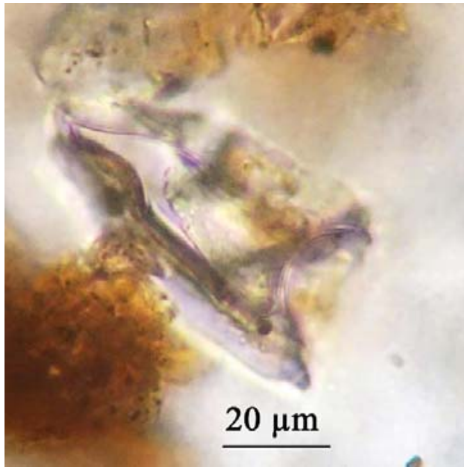
Cerealia

Verson st 95 n°6517

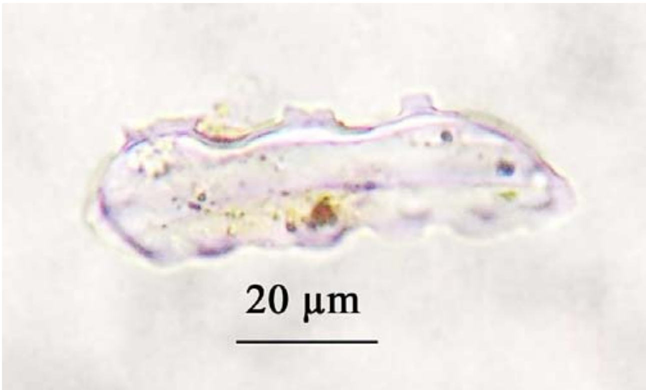
PHYTOLITHS



Elongate dendritic



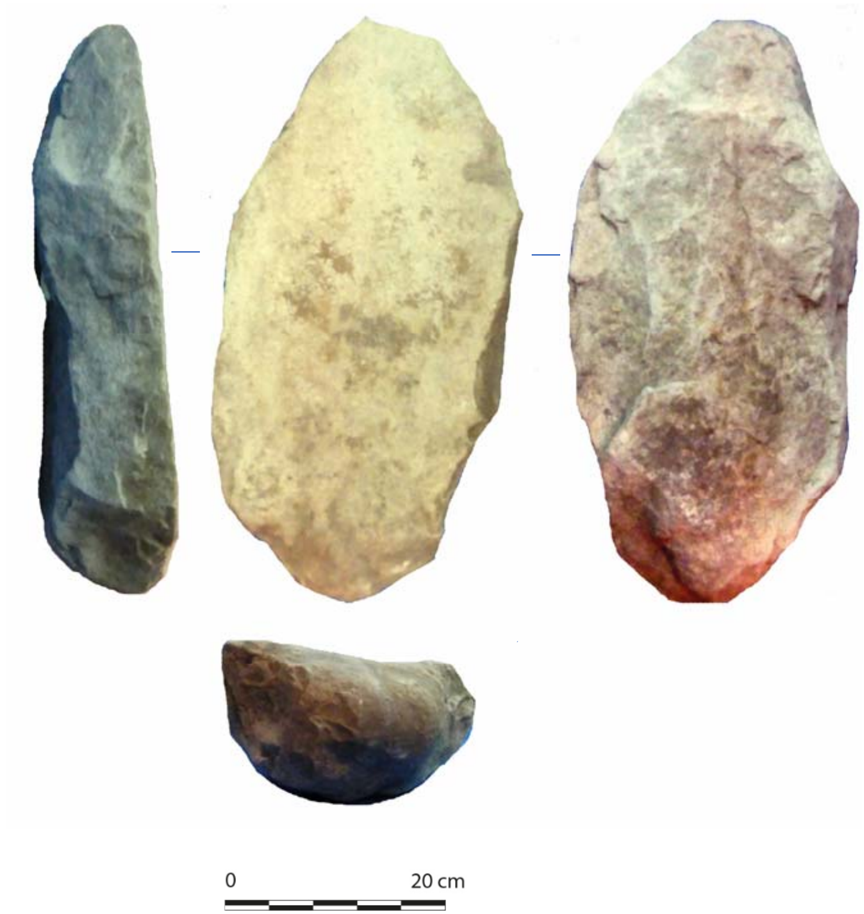
Blocky irregular



Trapezoid base sinuate

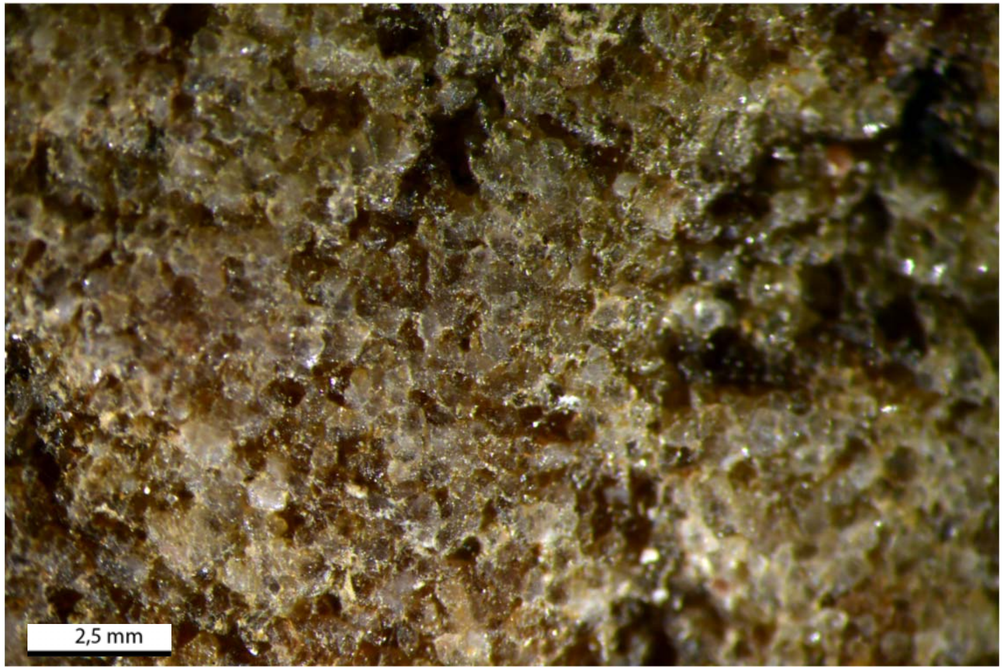
Choisy st. 120-256 n°3848

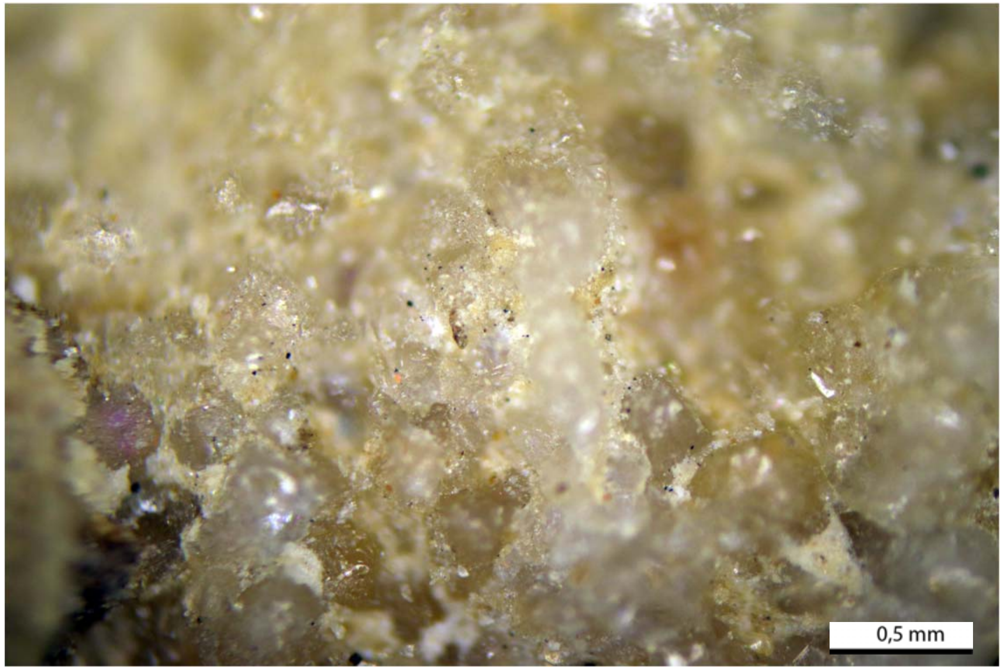
TOOL



Choisy st. 120-256 n°3848

USE-WEAR TRACES

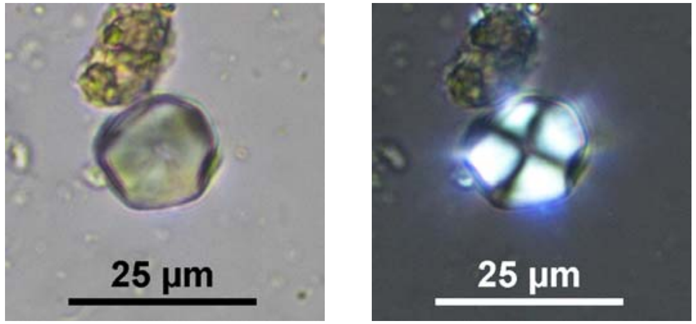




Choisy st. 120-256 n°3848

STARCH GRAINS

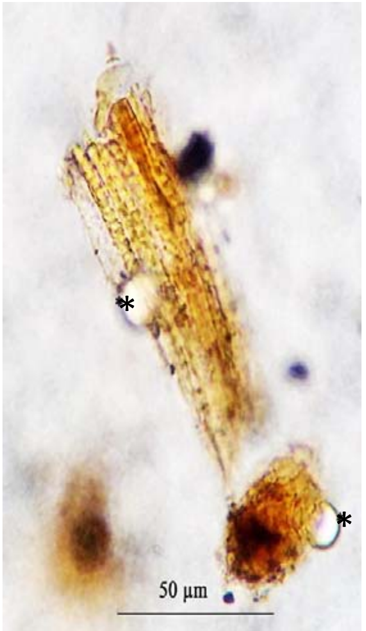
Starch mass

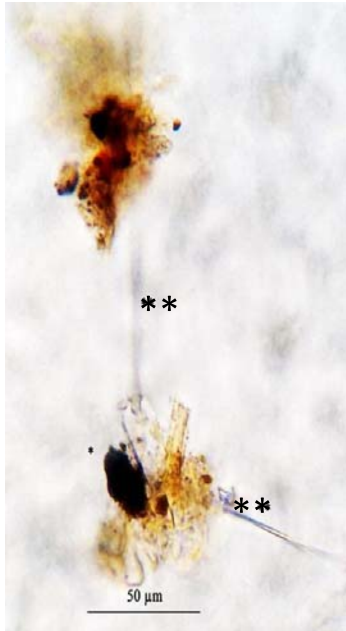


Cf. *Setaria* sp.

Choisy st. 120-256 n°3848

PHYTOLITHS





Plant residue and starches*

Plant residue and raphides**