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The search for a needle in a haystack – New studies on plant use during the Mesolithic in southwest Central Europe

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A B S T R A C T

The existence of Mesolithic agriculture is a subject of debate in the archaeobotanist community. So far, reliable and AMS-dated on-site evidence of cereal macro remains are lacking to support the hypothesis. Archaeobotanical analysis of two rock shelters with Mesolithic occupation layers in NE-France and SW-Switzerland, namely Lutter, Abri St. Joseph (FR) and Arconciel, La Souche (CH), revealed the presence of cereal remains within the Mesolithic deposits. They gave rise to a possible answer to the question, however direct dating of the individual cereal grains revealed their intrusive nature in the older deposits. The main aim of this paper is to place the newly acquired data from both sites in the broader framework of archaeobotanical research on Mesolithic sites in Central Europe with a special focus on methodological and taphonomic issues often encountered at such sites.

1. Introduction and aims

Archaeobotanical on-site studies are fundamental for the reconstruction of plant food resources of past times[1]. This also applies to hunter-gatherer societies, thus mainly archaeological settlements dating to the Palaeolithic and Mesolithic period. Much has been written about food strategies during the Mesolithic in Europe[2] (see e.g. Clarke 1976, Zvelebil 1994, Mason et al., 2002, Hather and Mason 2002). One of the main research topics in "Hunter-gatherer archaeobotany" is the exploitation of wild plant resources (Hather and Mason 2002), however questions about seasonality (see Dark 2004) and the transition to agriculture are also very much discussed (see in detail Hather and Mason 2002, and the earlier work of Zvelebil, i.e. Zvelebil 1994) and it is precisely this last issue that is the focus of this paper.

Despite important research questions, modern and systematic archaeobotanical investigations of Mesolithic sites are scarce. In recent years, much has been undertaken to improve the methods used in archaeobotany. For the given time period, the modern criteria within archaeobotanical research should involve: 1) Processing the entire excavated sediment (or at least a large part of it); 2) Measuring the volumes of sediment samples prior to sieving in order to calculate find densities; 3) Processing the sediment samples in a gentle way, to reduce loss of plant macro remains due to mechanical impact[3] (Hosch and Zibulski, 2003); 4) Describing identification criteria; 5) Evaluating the taphonomy and the stratigraphic affiliation of the finds through C^{14}-AMS dating of seeds/fruits. In our opinion, only using the above mentioned criteria increases the recovery of plant macroremains significantly and provides trustworthy results for cross-site analyses.

Archaeobotanical studies of Mesolithic sites are generally scarce. There are several reasons for this. First of all, plant remains are often very rare in pre-Neolithic deposits. This may be due to the nature of the hunter-gatherer societies (Hather and Mason 2002), the relatively short (probably mostly seasonal) occupation time of settlements (Bishop et al., 2013) or taphonomic issues. Secondly, previous studies have revealed that large amounts of sediment, if not all, have to be sieved in order to find seeds and fruits, i.e. the scarcity of remains may be due to the lack of

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[1] In the following only studies of seeds and fruits are considered. Charcoal analyses and on-site pollen analyses, which are far more available, are not considered.

[2] For the purpose of this paper, studies of hunter-gatherer sites in the Near East, with numerous publications on the "transition to agriculture", see. e.g. Ohalo II (Late Palaeolithic, Weiss et al., 2008) or the Early Layers of Tell Abu Hureyra (Epipalaeolithic; Hillman 2000; Colledge and Conolly 2010), are not considered.

[3] https://ipna.duw.unibas.ch/fileadmin/user_upload/ipna_duw/PDF_s/AB_PDF/ChaineOperatoire_Mineralboden.pdf

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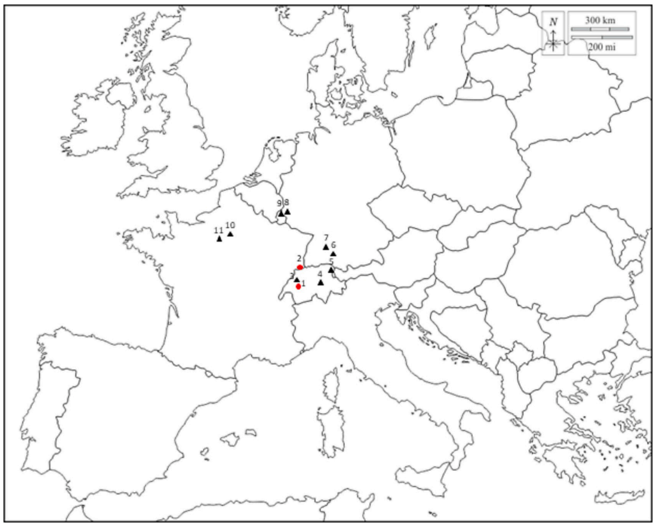

Fig. 1. Geographical location of the rock shelters Lutter - St. Joseph and Arconciel - La Souche, as well as archaeobotanically investigated sites in SW Central Europe. (1) Arconciel – La Souche (CH), (2) Lutter – St. Joseph (F), (3) Cornaux – Prés du Chêne (CH), (4) Muothatal – Berglibalm (CH), (5) Oberriet – Unterkobel (CH), (6) Henauhof Peninsula (D), (7) Rottenburg - Siebenlinden (D), (8) Hüttingen an der Kyll (D), (9) Berdorf – Kalekapp 2 (L) (10) Champigny – Mont St. Pierre (F), (11) Auneau – Parc du Château (F).

a strategy to recover them; furthermore, the density of plant remains hardly ever exceeds one find per litre of sediment. In addition, plant remains are often fragmented and poorly preserved, their identification is limited. Every so often amorphous objects are among the findings, i.e. remains of parenchymatous tissue of which the identification is difficult and only recognised by trained scientists (see Kubiak-Martens 1996, 2016). And last but not least, bioturbation (by animals and/or roots) is a common phenomenon especially in rock shelters and in the front part of caves, easily relocating plant macroremains to older or younger deposits and thus contaminating the archaeological deposits. C^{14} dating is a must in case of suspected contamination. Considering these issues, it can be said that the costs of studying plant remains from Mesolithic (as well as Palaeolithic) sites is high, yet the risk of an unsatisfactory result is existent if not probable. This should however never influence the need for an implementation of such analyses as an improvement of our rather poor knowledge of the proportion of plants in the diet of hunter/gatherer societies is highly necessary.

The starting point for this study are the results of the archaeobotanical analysis of two rock shelters with Mesolithic occupation layers in NE-France and SW-Switzerland, namely Lutter, Abri St. Joseph (FR) and Arconciel, La Souche (CH) (Fig. 1). Both sites are among the few Mesolithic sites in southwest Central Europe that have been systematically examined for plant remains. The search for traces of plant remains in Mesolithic layers is often a search for the proverbial "needle in a haystack". In the course of the excavation campaigns, many samples were taken and processed with modern archaeobotanical methods. In Lutter, one of the targets of the excavation was to develop a method which allows the recovery of artefacts on the one hand and the possible complete recovery of the very few, and fragile charred botanical remains on the other hand, therefore a specially adapted method of recovery was developed.

The aim of this study is to place the newly acquired data in the broader framework of archaeobotanical research on Mesolithic sites in Central Europe with a special focus on methodological and taphonomic issues often encountered at such sites. A holistic approach to hunter-gatherer archaeobotany is not the purpose of this study, however our results provide important – above all methodological – guidelines for future archaeobotanical research in Mesolithic sites.

cal. BC	Chronozones		Archaeological period	Culture
5000	Atlantic	to Late	Neolithic	Early Neolithic
6000		Middle	Transition	
7000		Early	Late Mesolithic	
8000	Boreal		Early Mesolithic	Beuronien C
				Beuronien B
	Pre-Boreal			Beuronien A
9500				Earliest Mesolithic

Fig. 2. Chronozones of the Early to middle Holocene and cultural periods of the Mesolithic in Central Europe (after Nielsen 1996; Taute 1975; Crotti 1993).

2. Current state of research

A compilation of the archaeobotanical results, considering only "seedy" remains, from sites from Southwestern Germany, Northeastern France including the South of Belgium and Luxemburg as well as Switzerland (for geographical location see Fig. 1, for cultural affiliation see Fig. 2) gave the following results:

Southwestern Germany: In the floodplain of the Neckar river in Rottenburg, several open air settlements known as Siebenlinden 1–2 und Siebenlinden 3–5 were discovered (Kind 2003; Kind and Beutelspacher 2009; Kind 2010; Kind et al., 2012). The archaeological layers of these sites (Siebenlinden 1–5) date from the late Pre-Boreal (8100 cal. BC, Beuronien B) into the middle Atlantic period (5600 cal. BC, Late Mesolithic). Unfortunately, very few archaeobotanical investigations have been carried out (Rösch 2000) and if so, not according to modern criteria (volume measurements etc.), which prohibits a comparison of the archaeobotanical results with other sites. Within the Beuronien B layer a fire pit full of charred hazelnut fragments was found and interpreted as nut-roasting pit. An extensive programme of C^{14} dating on macro plant remains has been conducted, through which - amongst others - the presence of younger intrusions in the Mesolithic horizons could be established (Kind et al., 2012, p 47 ff.). As a result, the (few) existing data need to be treated with caution. Furthermore, along the Lake Federsee, particularly in the area of the Henauhof Peninsula, numerous Mesolithic sites were found (Henauhof Nord I: Schlichtherle 1988; Henauhof-Nordwest: Jochim 1993; Henauhof Nord II: Kind 1997; Taubried II: Schlichtherle 2001). Once again, hardly any archaeobotanical investigations were done and none of the results are in line with modern methodology. The examination of plant remains from Henauhof-Nordwest did not provide any evidence of the processing of wild plant food, although the waterlogged soil did provide the ideal conditions for preservation (Gregg 1993). In Taubried II, a large number of hazelnut shells were found within an off-site deposit embedded in lake sediments. They were dated to the Late Preboreal (8530–8290 cal. BC, Beuronien A) and are likely originating from a nearby camp site (Schlichtherle 2001). The Lake Federsee sites date just like the Siebenlinden-sites from the Late Preboreal (Beuronien A) to the middle Atlantic period (Late Mesolithic) (no C^{14}-dates published). In the district of Trier, charred hazelnut shells were registered at the Mesolithic site of Hüttingen an der Kyll (Koch et al., 2017). AMS dating of a hazelnut shell dated the deposit between 8541 and 8282 cal. BC. Here too, botanical analyses were not systematically carried out and not according to modern criteria.

Northern France/Luxemburg/Belgium: Very few archaeobotanical studies exist from Mesolithic sites in northern France, Luxemburg and Belgium. In the Paris basin, the open-air site of Mont-St-Pierre, located in Champigny near Paris (Toulemonde unpublished) has been archaeobotanically investigated. One pit (radiocarbon dated to the Early Mesolithic (8331–8216 cal. BC)) and a burial (radiocarbon dated to the Late Mesolithic (6348–6067 cal. BC)) were analysed according to modern criteria. Only hazelnut fragments were found, their density does not exceed one item per litre of sediment. At the Mesolithic site of « Parc du Château » at Auneau (Eure-et-Loir), seventy pit structures were dug. And although plant remains were lacking, the hypothesis of subterranean storage of nuts was put forward (Verjux 2017). In Luxemburg, the Mesolithic rock shelter of Berdorf-Kalekapp 2 (no C14-dates published) (Leesch et al., 2017), yielded vast amounts of hazelnuts. They were collected using a 3 mm mesh size, no other plant remains were considered. It is suggested that the hazelnut shells are the result of waste material and not of storage. From Belgium, there are some records of hazelnut shells in Mesolithic sites (Vermeersch 1989), however no recent studies are known.

Switzerland: three sites with Mesolithic layers have been at least partially investigated, they include: the rock shelter of Unterkobel near Oberriet (SG) (Wegmüller and Hajdas, 2022; Akeret, 2022), the rock shelter of Berglibalm in the Muotathal (SZ) (Leuzinger and Affolter, 2016; Leuzinger et al., 2020) and the settlement of Prés du Chêne in Cornaux (NE) (Martinoli and Jacomet, 2008). In the rock shelter of Unterkobel by Oberriet (7970–6073 cal. BC Wegmüller and Hajdas 2022) a total of 63.5 L of sediment from the Early and Late Mesolithic layers were processed, the concentration of plant macroremains varied between 0.4 and 21.7 items per litre of sediment; mainly hazelnut shell fragments, elderberry (*Sambucus* spec.) seeds and a few fragments of blood dogwood stones (*Cornus sanguinea*) were found (Akeret, 2022). In the rock shelter of Berglibalm in Muotathal, dating to the Early Mesolithic (8766–7596 cal. BC), information on the volume of studied soil samples is not known, a few fragments of hazelnut shells and a yew seed (*Taxus baccata*) were identified (Leuzinger and Affolter, 2016; Leuzinger et al., 2020). In Cornaux/Prés du Chêne (NE) (no C^{14} date available), 7.75 L of sediment were experimentally sieved and studied, few plant macro remains were retrieved (Martinoli and Jacomet, 2008). Two hazelnut shell fragments, a stone fragment of blood dogwood and 24 fragments of charred amorphous objects, possibly from roots, bulbs or rhizomes were determined. Unfortunately, the project did not continue.

In summary, the state of research is rather poor in Southwestern Central Europe. In other parts of Europe, archaeobotanical analyses of Mesolithic sites have been carried out time and again, and the state of research varies from region to region. In the following we give a brief summary of the existing studies.

From Eastern Central Europe and the Balkan area there are few ‘modern’ archaeobotanical studies. Interesting and according to modern criteria are the results of parenchymatous tissue analysis from Early Mesolithic layers in Calowanie (Kubiak-Martens 1996; Kubiak-Martens and Tobolski, 2014) and the Late Mesolithic site at Dabki (Kalis et al., 2015) both in Poland, establishing the collection of starchy plants and their preparation for consumption as part of the vegetable diet. The combined macro- and microscopic botanical analyses of the Mesolithic camp of Kopanica (P) evidences specific human activities (Sobkowiak-Tabaka et al., 2020). Another multi-proxy archaeobotanical analysis exists from the Late Mesolithic site of Melnycha-Krucha in South-West Ukraine (Salavert et al., 2020). Yet seeds/fruits were not recorded, which might be due to the small sample size and/or the poor preservation of plant macro remains in general. From the Czech Republic, data is very scarce (Divišová and Šída, 2015). Then again, in Dolni Vestonice the first archaeological parenchyma has been identified in a European context in upper Palaeolithic layers (Mason et al., 1994; Pryor et al., 2013). The archaeobotanical data published from Schelah Cladovei in Romania, C^{14} dated to the 8th millennium BC, is very vague (Mason et al., 1996; Mason et al., 2002). A modern study of seeds and fruit from the late Mesolithic and Mesolithic/Early Neolithic site Vlasac in Serbia, which is situated in the Danube Gorges area, exists (Borić et al., 2014; Filipović et al., 2010; Marinova et al., 2013). Although no cereal grain was found, the analysis of starch granules recovered in dental calculus of Mesolithic human teeth revealed the consumption of domestic cereals at the site (Cristiani et al., 2016).

From northern Germany there exist archaeobotanical studies from rock shelters in the southern Leinebergland (distr. Göttingen, Niedersachsen, D) (Wolf 1994). Several of these include a Mesolithic occupation layer. Of particular interest is the Abri Reinhausen / Bettenroder Berg IX. From this site 260 samples were examined, unfortunately, information on the volume of processed sediment is lacking. The stratigraphy of the rock shelter extends from the Alleröd (Federmesser culture) to the Early Atlantic (Late Mesolithic / Early Neolithic period). Particularly rich in plant macro remains are the Early Mesolithic layers with a predominance of hazelnut. In the Late Mesolithic / Early Neolithic layer (6th millennium BC), a single barley grain and an emmer glume fragment were identified. They are thought to be “imported” from contemporaneous Linear Pottery settlements in the area, however no C^{14} dates of these cereal finds are available to prove their authenticity. Also in northern Germany, NE of Hamburg, is the Duvensee bog where numerous Mesolithic sites have been excavated (see Groß et al., 2019). They date from the late Preboreal (around 8900 cal. BC) to the early Atlantic eriod (around 6500 cal. BC) and are considered representative for Mesolithic research in Germany. The settlements along the Duvensee bog are characterized by excellent conditions of preservation; due to waterlogging organic remains are abundant. At a few sites, hearth structures defined as hazelnut roasting places were excavated. Two of them, dating to the late Preboreal (Wp 8) and the Boreal (Wp 6), are investigated in detail, discussing the role of hazelnuts in the subsistence strategy (Holst 2010; Holst 2007). At the Mesolithic sites of Friesack 4 and 27 in Brandenburg charred and waterlogged plant remains were found; the use of wild plants gathered in the surroundings of the sites is confirmed; hazelnut represent the most important supply of calories (Jahns and Wolters, 2021).

Relatively good is also the state of research on the coasts of NW-Europe, i.e. in the Netherlands (see Out 2009) or in southern Scandinavia (see the compilation of Regnéll 1998 or currently Regnell, 2011), often including the identification of parenchymatous tissue (Kubiak-Martens 1999; 2002; Kubiak-Martens et al., 2015; Perry 2002). In the British Isles, many sites were investigated (see Milner et al., 2011, Bishop et al., 2013), every so often showing very good preservation of waterlogged organic remains while located on the coast or on lakes. In Scotland, plant remains are generally scarce in Mesolithic sites, which is partly due to the methods used for their recovery. Hence it could be established that definitively hazelnuts but possibly a much greater range of plants were part of the vegetable diet (Bishop et al., 2013). The landscape and as such the subsistence potential of the Mesolithic sites in the NW European coastal areas differ a lot from our own region of research, therefore we refrain from a detailed description of their results.

Compared to Central Europe, the state of research in southern Europe is also much better. From the Iberian Peninsula, data from fifteen sites, mostly caves and rock shelters, is available (Antolin et al., in press). Archaeobotanical analysis has been carried out in different ways, with only few sites using ‘modern’ processing techniques. Worth mentioning is the analysis of the cave Aizpea in the Pyrenees, where Late Mesolithic sediments were examined systematically and according to modern criteria (Zapata et al., 2002). Among the wild food plants, hazelnuts and Pomoideae fruits seem to have been an important resource in the Mesolithic Iberian Peninsula. From southern France several highly interesting and important sites have been archaeobotanically investigated; these are mainly caves and rock shelters, such as the Mesolithic site of Baraquettes IV (Cantal Dept.) (Bouby and Surmely, 2004) and the rock shelter La Grande Rivoire (Martin et al., 2012; Angelin et al., 2016) which have been studied according to modern criteria. On both sites hazelnuts represented the most important plant food resource. From the Grotte de l’Abeurador (Hérault Dept.) (Heinz et al., 1992; Vaquer and Ruas 2009), the rock shelter Usclades (Ardèche Dept.) (Maury and Frayssenge 1990) and the cave Baume de Fontbrégoua (Var Dept.) (Savard 2000) sample volumes were not measured; densities of plant macro remains as well as quantitative comparisons with other sites are not possible. In all three rock shelters charred seeds and fruits of legumes such as pea (*Pisum*), vetchling (*Lathyrus*) and vetch (*Vicia*) were found, which is remarkable within Mesolithic deposits. It is thought that intensive gathering took place. In the cave Baume de Fontbrégoua possible cereal contamination in the Mesolithic layers is mentioned, no C^{14} dates are available.

Sites even further away from our area of research and mentioned only at margins include Grotta dell'Uzzo in Sicily (Costantini 1981; Costantini et al., 1987) and the Franchti cave in NE Greece (Hansen 1991). A recent overview of archaeobotanical analyses in Greece shows the still very limited dataset of Mesolithic sites (Kotzamani and Livarda 2018). However, as environmental conditions vary these sites are not directly comparable to our Central European sites.

To summarize: the state of archaeobotanical research in southwest Central Europe is very poor, whereas from the north and the south of Europe more information is available, indicating the importance of roots and tubers in the Mesolithic diet on the one hand and showing a manifold use of gathered plants on the other hand.

3. Methodology and Results: The sites, the sample processing and the archaeobotanical record

3.1. Lutter (Dép. Haut-Rhin 67, Alsace, France), Abri St. Joseph

3.1.1. The site

The prehistoric site "St. Joseph" in the village of Lutter (Alsace, Dép. Haut-Rhin, France) is a rock shelter located at the border between the hilly Loess-landscape of the Sundgau and the Jura mountain chain, 25 km south west of Basel (CH) (Fig. 1). It was discovered through trial trenches in 1983 by the University of Strasbourg (Ch. Jeunesse). Annual excavations have been conducted between 2005 and 2011 by an international team of researchers from the universities of Strasbourg (UMR 7044, CNRS - University of Strasbourg) and Basel (IPAS) yielding cultural deposits from the Mesolithic to the Neolithic (Jeunesse et al., 2014). 34 C14-AMS-dates were obtained from hazelnut shells, charcoal and cereal grain fragments (see Jeunesse et al., 2014, p. 43-44), they point to several occupation phases: a first one is corresponding to the early to middle Mesolithic (layers 9 and 8; 8610–7180 cal. BC); it is followed by a hiatus (mostly layer 7); the late Mesolithic is represented by a C14-date from the 1st half of the 6th mill. cal. BC. Finally, there are several dates between 5310 and 2620 cal. BC, pointing to several occupations during the Neolithic. Most of the dates, mainly coming from layers 5 and 4 can be attributed to the period between 5300 and 4400 cal. BC. Layer 3 was formed between the end of the 4th mill. cal. BC and the early 3rd mill. cal. BC.

The main aim of the archaeobotanical studies in Lutter was to develop new, quantitative evidence of the subsistence strategies during the Late Mesolithic – Early Neolithic in the northern Jura - southern Upper Rhine plain and adjacent areas. Fig. 3 shows a large part of the stratigraphy of the rock shelter Fig. 3 (from Arbogast et al., 2011). In a small test-trench a clearly visible layer of the early Mesolithic (layer 9), with plenty of charcoal was found (not visible on Fig. 3; the test trench was situated 2 m to the west in the northern part of the rock shelter). Above this layer, the stratigraphy is much influenced by natural phenomena like weathering of rocks, landslides and alluvial import from the nearby stream etc. (Jeunesse et al., 2014, p. 19 ff.); in addition, the layers are heavily penetrated by roots. There are certain layers with more anthropogenic influence as for example layer 4. The period of interest (Late Mesolithic-Early Neolithic) is represented by the uppermost part of layer 7, layers 6, 5 (only visible in some parts of the rock shelter) and 4. Although there were relatively many archaeological remains (mainly stone artefacts and some small fragmented ceramics or limestone), clear structures of anthropogenic source like fire places could not be found (see Jeunesse et al., 2014). The stone artefacts of layers 7 to 4 mainly point to an autochthonous substrate ("indigenous" Mesolithic people); the ceramics however show signs of influence from the nearby upper Rhine area (like "Grossgartach"; Jeunesse et al., 2014). It remains unclear though what caused this mixture.

During excavation, all of the excavated sediments were systematically sieved. They contained a very high amount of (calcareous) stones, in a matrix of compacted clay. Due to this soil-texture a standard sieving procedure for the recovery of plant macroremains could not be applied, a more elaborate method was required to deal with these extremely difficultly disintegrating sediments. In the following a detailed presentation of the methodological procedure and their results is presented, as well as first archaeobotanical results for the two main time periods, namely the Early Mesolithic and the Late Mesolithic. Based on the samples analysed, it is possible to obtain first, important conclusions, in terms of the methodology as well as plant use. All plant remains are recovered in a charred state of preservation as the archaeological layers of the rock shelter are located above the groundwater level.

3.1.2. Methodology

In order to loosen the (very little) organic material from the sediment without destroying it, and without polluting the nearby stream from which water was taken for sieving - with chemicals, a method of its own was developed. It basically requires two succeeding sieving stages (Fig. 4).

The first sieving stage involves a gentle wet-sieving of the soil. After the usual steps of sediment description, soaking of the sediment in water and measurement of its volume (Antolín et al., 2015), samples were divided into two categories (Fig. 4). Those without visible archaeobiological content (e.g. floating charcoal) were wet-sieved using mesh sizes 4 and 2 mm to retrieve archaeological small finds (e.g. silices, beads, etc.) (so-called archaeological sieving); those samples which did appear somewhat darker, were of special interest, or yielded charcoal during soaking, were treated differently (archaeobiological sieving). They were sieved gently - without "force" - using mesh sizes 4 mm 1 mm and 0.35 mm[4]. The sediment was carefully rinsed through the 4 mm sieve, larger charcoals as well as archaeological and zoological material were continuously sorted out, dried and packed for analyses. All unworked stones were discarded; the latter corresponded to more than 50 % of the material. In the 1 mm and 0,35 mm-sieves, mainly clay-concretions and loose organic remains were collected. During the sieving process, the 1 mm and 0.35 mm sieve were checked: If no organic material was visible, the clay collected in both sieves were discarded and the sample treated as an archaeological sample. If the 1 mm and 0,35 mm sieve contained organic material, the heavy residue of these small fractions were gold-washed using a very small sieve-mesh size (0.063 mm). The floating organic material was dried and packed ready for analysis; the inorganic material from both small fractions - mainly clay clumps - was packed separately (see below). This completed the first step in the sieving process.

The inorganic outcome of the first sieving stage, mainly clay clumps, were subsequently prepared for the second sieving stage by means of a pre-treatment (Vandorpe and Jacomet 2007). Drying of the sediments prior to sieving did not give satisfactory results, thus it was opted to use the freeze–thaw method as this resulted in an easier and more extensive disintegration of the clay.

The frozen-and-thawed clay material from the "organic? worthwhile" samples of the first sieving procedure was again soaked in water, its volume was measured. The wash-over method was then used to separate mineral and organic parts as gently as possible (Hosch and Zibulski 2003). Sieves with mesh sizes of 1 mm and 0.35 mm were operated. The organic material remaining in the sieves was gold-washed and then laid out to dry before analysis. The inorganic part (stones, but mostly still clay clumps) was rinsed and finally mechanically pressed

[4] If a sample was relatively rich in charred remains, the so-called wash-over technique was applied from the beginning (described in Hosch and Zibulski 2003). The experience soon showed however that, this technique is not suitable for clayey sediments, as there is hardly any floating organic material (except for modern roots).

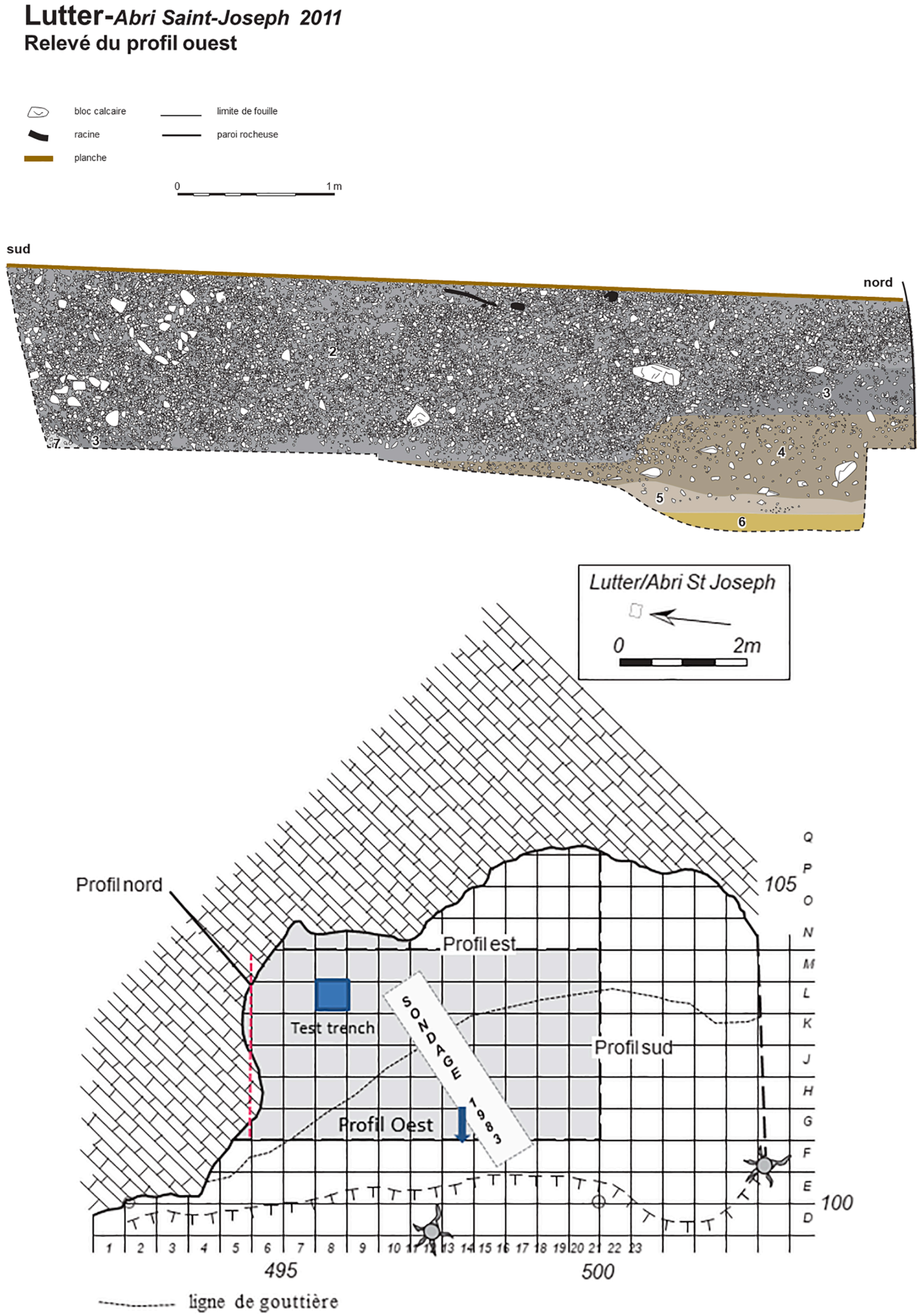

Fig. 3. Lutter - St. Joseph. a) Stratigraphy of the western side of the excavation. b) Plan of the excavated area. (from Arbogast et al., 2011, Fig. 14, page 25, drawing by A. Denaire).

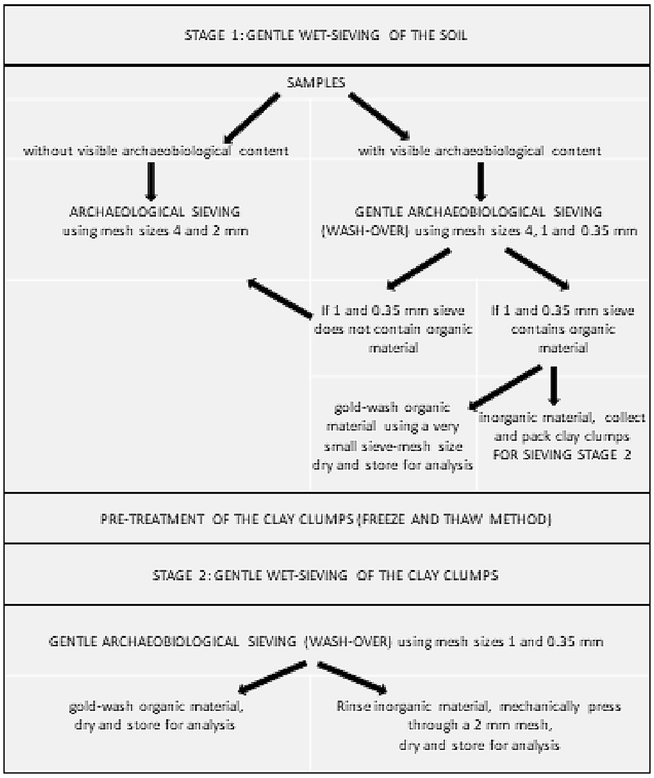

Fig. 4. Schematic presentation of the sieving process developed in Lutter.

through a 2 mm sieve as a last step. Any charcoal or charred hazelnut shells that appeared during this very last step were picked out manually and added to the previously separated organic material. The inorganic remains were also dried and stored, as they e.g. often contained bones or teeth from small mammals. This completed the second step in the sieving process.

3.1.3. Results

Methodology

In total approximately 8 tons of sediment were processed, of which 4.2 tons were sieved for archaeobiological remains (stages 1 and 2). This corresponds to 868 samples, of which 605 could be assigned to a layer. The average sample volume was about 5 L. For the second sieving stage, the focus lay on those layers, representing the Early Mesolithic (layer 9) and the Late Mesolithic / Early Neolithic transition period (mainly layer 5). From these layers, 178 samples are available.

A comparison of the numerical values after the 1st and 2nd stage in the sieving procedure using the example of layer 5 shows the necessity of a more elaborate method to extract charred botanical remains from very clayey deposits (Table 1). The majority of the remains is recovered after the second sieving stage (432 remains after step 2 versus 214 after step 1). This is particularly true for most of the hazelnut shell remains (*Corylus avellana*) (346 after step 2 compared to 120 after step 1) and seems to be linked to their higher specific weight as well as their poor floating capacity. In addition, these remains were often embedded in clay nodules. As a result, hazelnut shell fragments were mainly collected in the last phase of treatment when the last clay nodules were crushed (see above, Fig. 4). Other plant macro remains are retrieved more evenly after sieving steps 1 and 2 (89 versus 79 including AOC = amorphous charred objects), which can be explained by their more porous structure.

The newly developed method allows a clean and gentle recovery of all type of remains. It is time-consuming as the sediment has to be sieved twice and it requires a large infrastructure with several sieving installations and enough trained people to operate them. However, the results underline the interest and the essential nature of a second sieving

Table 1
Lutter- St. Joseph. Archaeobotanical results of layers 5 and 9, including a comparison of the data retrieved after sieving stages 1 and 2 from layer 5. All plant remains are charred and represent seeds or fruits if not otherwise specified.

		Layer 5 - analyses 2009 and 2010			**Layer 9**
Number of samples		**36**			**15**
Total volume of samples (l)		**191.5**			**86.5**
Sieving stages		Total after Stage 1	Total after Stage 2	Total	Total after Stage 1
Cereals	**English name**				
Hordeum sp.	barley	1	.	1	.
cf. *Triticum* sp.	wheat	1	.	1	.
cf. Cerealia indet.	cereal	6	8	14	.
Plants of forests, forest edges and clearings					
*Corylus avellana**	hazelnut	120	346	466	895
cf. *Corylus avellana**	hazelnut	5	7	12	.
Tilia sp.	lime	.	5	5	.
Other					
Galium sp.	bedstraw	.	.	.	2
Rumex sp.	dock	1	.	1	.
Indeterminata - s/f	not determined	4	5	9	.
Indeterminata - fruit stone fragment	not determined	8	11	19	.
Indeterminata - amorphous objects	not determined	68	50	118	152
Total		214	432	646	1049
Density		1.1	2.3	3.4	12.1

stage in order to obtain the most complete possible coverage of the charred macroremains.

Plant remain spectrum of the Early Mesolithic (layer 9)

During the last excavation campaign in 2011 a cultural layer (layer 9) of the Early Mesolithic was found in a small test trench. Samples taken in this layer 9 revealed the existence of a deposit very rich in charred material and bones. Layer 9 represents the first evidence of the Early Mesolithic on a regional scale. So far, 15 of the 59 samples have been analysed (Table 1)[5]. It concerns only the organic material retrieved after the 1st sieving stage. Almost all samples are characterized by a high concentration of hazelnut shell remains (some of which have been directly C^{14} dated) with concentrations often well above 10 fragments/litre and a maximum of 21.4 fragments/litre. In addition to the numerous hazelnut shell remains, one sample yielded two seed fragments of a bedstraw (*Galium*). It is probably cleavers (*Galium aparine*), which is currently widespread as a ruderal plant growing in rich and humid places and indicative of anthropogenic environments and as such also fairly widespread in the Mesolithic. The samples from layer 9 were also rich in amorphous objects, some of which are related to bones, but a large proportion of which are of undetermined origin and could represent the remains of fruit flesh and parenchymatous tissue (see Kubiak-Martens 2016).

Plant remain spectrum of the Late Mesolithic to the Early Neolithic (layer 5)

The upper part of layer 7, layers 6, 5 and 4 date to the Late Mesolithic, at the transition to the Early Neolithic (ca. middle of the 6th mill. BCE). This is also the period of the earliest introduction of agriculture to central Europe (see below). Through C^{14}-dating a time span between 5800 and 4600/4400 cal. BC was obtained (Jeunesse et al., 2014, p. 17).

[5] All archaeobotanical data are stored in the internationally used archaeobotanical database ArboDat (Kreuz and Schäfer, 2014).

The botanical analyses focussed on layer 5, which could be C^{14}-dated between 5790 to the late 5th mill. cal. BC. One of the objectives of the excavation was to try and find cereal remains from this period of transition. 36 of the 113 samples taken in this layer have been analysed, they include the "visibly" richest ones in charred material (Table 1). Seeds and fruits are generally rare, which can be explained by the lack of archaeological structures (Arbogast et al., 2011; Jeunesse et al., 2014). A total of 646 charred macro remains were found, of which 432 remains only after the 2nd sieving stage. The density of plant macro remains is 3.4 items per litre of sediment. Compared to other sites, this is rather high and can probably be linked to the complex sieving method, which contributes to a more extensive recording of the charred remains than is normally the case.

The most frequent plant macro remains were hazelnut shells (466 of the 646 identifiable remains; Table 1), they were present in more than 90 % of the samples, their density varied between 0 and 20 items per litre of sediment. In addition, five fruits of lime (*Tilia* sp.), 19 fragments of undetermined fruit stones - some still with fruit flesh (cf. *Prunus spinosa*) - and a small fruit of dock (*Rumex* sp.) were found.

Single cereal remains were also found. In one sample the apical end of a wheat grain (*Triticum* sp.) was found as well as another grain fragment which could not be identified in detail (cf. *Hordeum*). In seven other samples, a total of 13 "cereal grain-like" looking fragments were found, which could not be further identified ("cf Cerealia"). Two cereal remains were AMS dated and yielded the following result (Table 2): Date 1 is in the early phase of the Late Neolithic (ETH-44985: 5195 ± 35 BP, gives a calibrated date between 4060 and 3950 BCE, 95.4% probability); Date 2 is in the middle phase of the Late Neolithic: ETH-44984: 4375 ± 30 BP, gives a calibrated date between 3090 and 2900 BCE (94.4% probability). It is clear that the cereal remains represent younger intrusions within the Late Mesolithic layers (probably from layer 3, Jeunesse et al., 2014) in the rock shelter. Similar intrusions have been observed elsewhere and seem to be a common problem within Mesolithic dryland sites (see below).

3.2. *Arconciel, La Souche (canton of Fribourg, Switzerland)*

3.2.1. *The site and applied methods*

The Arconciel/La Souche rock shelter is located in the canton of Fribourg, in the southwest of the Swiss Plateau. The site was first discovered in 1998. Between 2003 and 2012, a combined program of rescue, research and teaching excavations were carried out each summer by the Service archéologique de l'État de Fribourg (SAEF) (Mauvilly 2008). Archaeological deposits of about three meters thick comprised an uninterrupted occupation from the end of the Early Mesolithic, the entire Late Mesolithic to the beginning of the Neolithic (7100/7000–4900/4800 BCE) (Fig. 5). The extent of the stratigraphy as well the excellent state of preservation of the archaeological deposits in the rock shelter of Arconciel/La Souche provide a reference point in the study of hunter gatherers on the Swiss Plateau. According to the stratigraphy, six phases were identified. They correspond to archaeo-sedimentary units, named I to VI, of which unit VI represents the oldest level and unit I the most recent level. During excavation, all of the excavated sediment was wet-sieved for the recovery of archaeological finds. In addition, 522 samples - which corresponds to 1098.2 L of sediment - were processed for the recovery of plant macroremains using the wash-over method (Hosch and Zibulski, 2003; Jacomet 2013). Processing of the samples did not pose the same problems as encountered in Lutter. The rock shelter of Arconciel was cut by the river Saane into marine molasses. This resulted in a rather loose and sandy sediment with a low clay content. Therefore, standard sieving methods (wash-over) could be applied. The sediment samples come from various contexts, the majority of which were hearths.

3.2.2. *Results*

A total of 2′127 seeds and fruits were sorted and analysed (Table 3)[6,7], their preservation is average with a relatively high fragmentation rate, which made the identification of the remains rather difficult. All plant macroremains are preserved in charred form. 380 of the samples studied, i.e. almost three quarters, did not yield any plant macroremains. In the remaining 142 samples the concentration of plant macroremains varied between 0.05 and 216 remains per litre. 50 % of the samples contained less than one item per litre and 93 % less than 10 items per litre. The average density is 1.9 remains per litre of sediment. The highest concentrations of seeds and fruits are found in units I and IV.

In total, 25 plant taxa were identified through the study of plant macroremains (excluding charcoal). The plant species include both cultivated and wild taxa. The latter represent 95% of the total number of identified plant macroremains and represent mainly forest and forest edge plants (n = 895), of which 13 species are foraging plants. Hazelnut is the most recurrent species, present in 6.3% of all samples, it was found in each unit, 62 shell fragments were identified. It is followed by mistletoe (*Viscum album*), which is present in 2.5% of the samples, and for which 17 seeds from units III to V were identified. However, the vast majority of forest and forest edge plants are present in less than 1% of all samples (see TAB. 1), e.g. blood dogwood (*Cornus sanguinea*), common juniper (*Juniperus communis*), apple or pear (*Malus/Pyrus*), raspberry (*Rubus idaeus*), common bramble (*Rubus fruticosus*), black elder (*Sambucus nigra/racemosa*) and small-leaved lime (*Tilia cordata*). A large number of amorphous carbonised fragments were found (283 fragments), they are present in 14.5% of the samples. It is likely that they represent food remains, fruit flesh or underground plant parts (roots, bulbs or rhizomes).

In addition to the wild plants and amorphous objects, a few cultivated plants were detected. Cereal grain and chaff were present in five samples belonging to units II to VI. One grain of oats (*Avena* sp.), two grains of barley, three grains and five rachis fragments of naked wheat (*Triticum aestivum/durum/turgidum*) as well as 18 grains and 13 rachis fragments of cereals which could not be identified to genus/species level were found.

Four samples of cereal grain were selected for radiocarbon dating (Table 2). They come from four hearths in units V, III and II (see Fig. 5a). The AMS dates of the cereal grains from unit V, III and II produced dates of 1679 ± 33 BP (330–420 cal. BC) (Ua49868), 1689 ± 33 BP (331–410 cal. BC) (Ua49867), 627 ± 31 BP (1295 – 1397 cal. AD) (Ua 70990) and 87 ± 30 BP (1808–1923 cal. AD) (Ua70989) respectively. These dates do not correspond to the chrono-typological data of the layers in which they were found. It is therefore clear that the cereals represent more recent contamination within the Mesolithic layers. Unlike the cereal grains, the AMS dates of hazelnut shells from unit V and III produced respectively dates of 7346 ± 35 BP (6191–6100 cal. BC) (Ua52384) and 6795 ± 35 BP (5720 – 5660 cal. BC) (Ua52383). These dates correspond to the Late Mesolithic and the chrono-typological data from these levels.

4. Discussion

4.1. *Methodological aspects*

As the example of the Abri of Lutter St. Joseph showed, layers in rock shelters of calcareous areas may contain sediments which are extremely complex to sieve (i.e. strongly compacted, many stones, rich in clay). During the campaigns of our scientific excavation we were able to develop a method which allows the extraction of much larger amounts

[6] All plant remains data are recorded and stored in the internationally used archaeobotanical database ArboDat (Kreuz and Schäfer, 2014).

[7] Preliminary results were published in Jacomet and Martinoli (2008).

Table 2
Results of the C14 Dating of plant macro remains from Lutter - St. Joseph and Arconciel - La Souche.

Lutter Abri St. Joseph (F)						
Sample n°	Layer	Material	N° Labo	Date [BP]	68,2% probability	95,4% probability
6169	5	cereal grain	ETH –44984	4375 ± 30	3015–2925 BCE	3090–2900 BCE
6433	5	cereal grain	ETH –44985	5195 ± 35	4040–3810 BCE	4060–3950 BCE
Arconciel La Souche (CH)						
Sample n°	Unit	Material	N° Labo	Date [BP]	1 Sigma calibrated result68.2% probability	2 Sigma calibrated result95.4% probability
721	2	cereal grain	Ua70989	87 ± 30	1697–1723 CE	1808–1923 CE
813	3	hazelnutshell	Ua-52383	6795 ± 35	5720–5660 BCE	5735–5635 BCE
976	3	cereal grain	Ua-49867	1689 ± 33	331–410 CE	251–430 CE
1124	3	cereal grain	Ua70990	627 ± 31	1301–1325 CE	1295–1397 CE
1003	5	hazelnutshell	Ua-52384	7346 ± 35	6191–6100 BCE	6271–6070 BCE
1006	5	cereal grain	Ua-49868	1679 ± 33	330–420 CE	250–430 CE

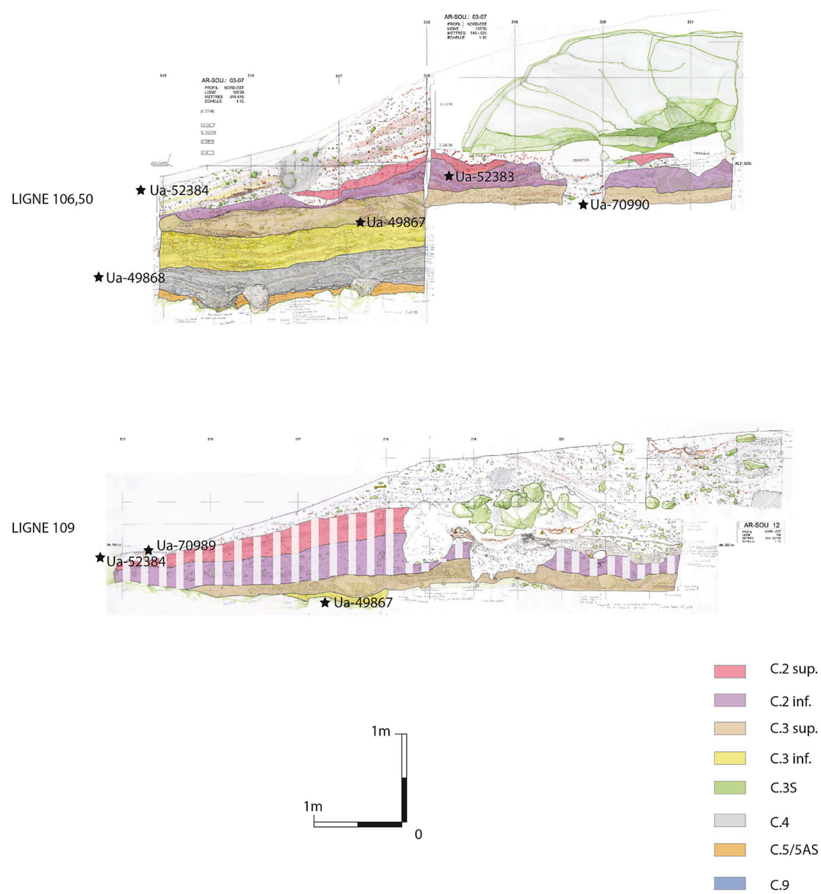

Fig. 5. Arconciel - La Souche. a) Stratigraphy of the site. b) Position of the profiles shown in a. © SAEF.

of charred material than usual (see above and Table 1), without the application of chemical additives (this is often not possible as one has to avoid ground- and stream-water pollution). However, this method is extremely costly in terms of time and workforce. In Lutter, 3 to 4 sieving stations were usually running parallel to each other, as a result more people were involved in the sieving of sediment than in excavating.

Thus the question remains: how rewarding is the archaeobotanical investigation of Mesolithic sites, as the input and output are not in balance? In retrospect we think that first of all only those sites which present structures like fireplaces are worth investigating. The latter has been put forward by Kubiak-Martens (2002), e.g. at the Halsskov site in Denmark where she identified pits and surface hearths as pit-cooking structures. These are best suited for the preservation of archaeological parenchyma and other food plant remains. Secondly the occupational layer should be protected since their embedding; and ideal would be the lack of younger layers - or at least thick, sterile deposits over a Late Mesolithic occupational layer. All in all, our results have shown that the investment is worthwhile when attempting to find out more about the Mesolithic diet.

4.2. Reflection on the formation of archaeological layers within rock shelters

When analysing plant macroremains from different sediment samples in an archaeological layer, we assume a priori that these remains are contemporary with the artefacts found in the same layer. However, if an unusual plant spectrum is found for the studied period, the integrity of the assemblage must be questioned and radiocarbon dating of the plant macroremains is strongly recommended / needed. Discrepancies between radiocarbon dates obtained from plant macroremains and those

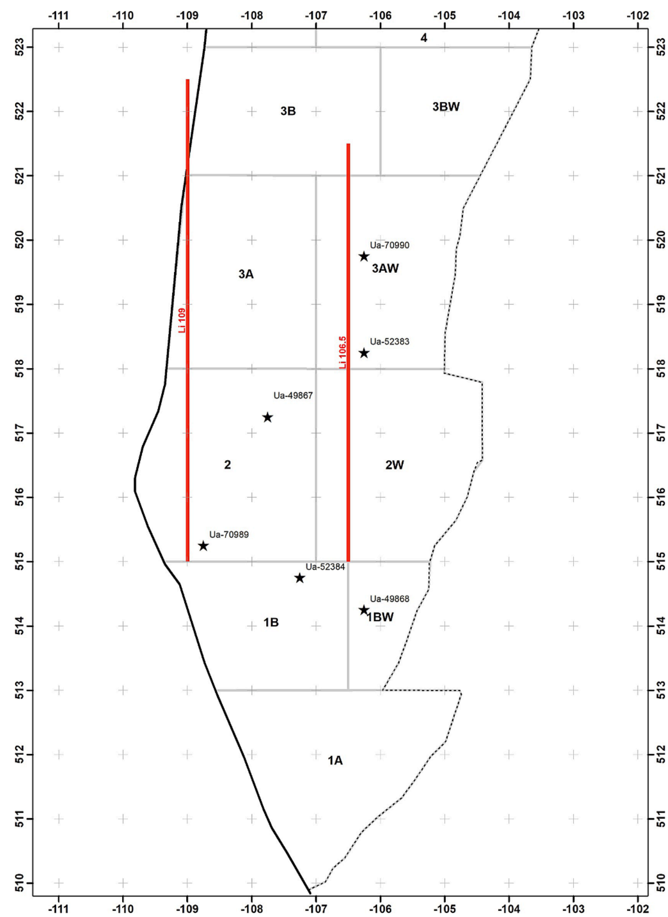

Fig. 5. (*continued*).

based on archaeological material were not only observed in the excavations we have analysed (see below, next paragraph). They have also been established in several other excavations; their nature has been attributed to different processes of bioturbation (Borojevic 2011; Kind 2010; Baines et al., 2015; Pelling et al., 2015). As such, cereal grain intrusions in Mesolithic deposits have been confirmed in more than a few occasions, e.g. in Staosnaig, on the Isle of Colonsay (W Scotland) (Mithen et al., 2001), in Siebenlinden (G) (Kind et al., 2012, 47 ff.), in Halsskov (DK) (Kubiak-Martens 2002) and in Can Sadurni cave (E) (Martínez-Grau et al., 2020).

The stratigraphic studies of the rock shelters of Lutter - St. Joseph and Arconciel - La Souche have shown that a large number of events, both natural and anthropogenic, took place during, but also after that the rock shelters were visited by Mesolithic people (see results-chapter). Unlike Lutter – St. Joseph, disturbances caused by burrowing animals have been observed in Arconciel - La Souche. At both sites, the presence of cereal grains in Mesolithic levels has raised many questions (see below). Consequently, the direct dating of individual plant macroremains, i.e. the cereals, was an absolute necessity. As mentioned above, the result of the ^{14}C dating differed from those expected on the basis of the archaeological material. In both sites, the cereal grains reflect a later deposit than the Mesolithic occupation. It has been argued that the presence of younger intrusions does not necessarily mean that all other macroremains or artefacts are equally younger (Baines et al., 2015). In Arconciel – La Souche, the AMS dating of hazelnut shell from the same context as one of the cereal remains resulted in a date corresponding to the chrono-typological data of this layer, namely 7346 ± 35 BP (6191 – 6100 cal. BC). In Lutter – St. Joseph, AMS dates of charcoal and hazelnut shells are equally contemporary with the chrono-typological data of the Mesolithic layers (see Arbogast et al., 2011, Rapport final, and Jeunesse et al., 2014). This raises the question of how the origin of the Mesolithic layers and the botanical remains within those layers are to be interpreted. It is clear that - at least - part of the remains are younger, hence - if not dated - we do not know which part.

In Arconciel- La Souche, the discrepancy between the C^{14} dates obtained from cereal grains and those based on archaeological material is certainly due to the activities of burrowing animals. Burrows have been observed throughout the excavation campaigns. In Lutter - St. Joseph, the evidence is not so clear. It is assumed that e.g. roots, snails, burrowing animals (whose traces were not obvious), landslides or percolating water are possible candidates for downward displacement. It is also possible that the Late Mesolithic Layer 5 in the rock shelter of Lutter is a colluvium containing material of different ages, which is shown by the wide range of C^{14} dates from this layer. As stated before and highlighted by our results, there is a need to assess post-depositional processes very carefully as well as to evaluate the sedimentary integrity and reliability of their archaeological content (Bernabeu et al., 2001).

4.3. *Exploitation of plant food resources in the Mesolithic*

Various foraging plants have been identified in both the Arconciel - La Souche and the Lutter-St. Joseph rock shelter. These include nuts, fruits, seeds and probably also underground plant parts such as roots and bulbs. Of all plant remains, hazelnut is the most recurrent plant in both sites. *Corylus* was one of the first deciduous woody species spreading in central Europe after the end of the last Ice Age (Lang 1994). Its development reached its maximum during the Boreal period. Hazelnuts appear to have been collected in large quantities during the early Mesolithic which is not astonishing as they were extremely widespread in the lowland-forests of the Boreal period. And although hazel was

Table 3
Arconciel - La Souche. Archaeobotanical results for each archaeo-sedimentary unit. All plant remains are charred and represent seeds or fruits if not otherwise specified.

Archaeo-sedimentary unit		I	II	III	IV	V	VI	Total	Ubiquity
Number of samples		25	55	137	166	75	64	522	
Total volume of samples		76.45	137.49	231.72	373.44	173.18	103.92	1096	
Cereals	**English name**								
Avena sp.	oats	.	.	.	1	.	.	1	0.19
Hordeum sp.	barley	.	.	.	.	2	.	2	0.19
Triticum aestivum s.l.	naked wheat	.	.	2	.	.	.	2	0.19
Triticum aestivum s.l. - rachis	naked wheat	.	.	5	.	.	.	5	0.19
Triticum aestivum/durum/turgidum	naked wheat	.	1	.	.	.	.	1	0.19
Cerealia indet.	cereal	.	.	11	.	7	.	18	0.57
Cerealia indet. - rachis	cereal	.	.	13	.	.	.	13	0.19
Plants of forests, forest edges and clearings									
Abies alba - needle	silver fir	.	.	.	2	.	.	2	0.38
*Cornus sanguinea**	blood dogwood	.	.	.	1	2	1	4	0.77
*Corylus avellana**	hazelnut	1	11	4	12	33	1	62	6.13
cf. *Corylus avellana**	hazelnut	.	.	1	2	.	.	3	0.57
Juniperus communis s.l.	common juniper	.	.	.	1	.	.	1	0.19
*Malus/Pyrus**	apple/pear	5	.	1	.	.	.	6	0.77
Picea sp. - needle	spruce	240	90	2	433	.	.	765	1.92
cf. *Quercus* sp.*	oak	.	.	.	2	.	.	2	0.19
Rubus fruticosus agg.*	common bramble	.	1	.	.	.	.	1	0.19
*Rubus idaeus**	raspberry	4	.	.	.	.	.	4	0.38
*Sambucus nigra/racemosa**	black elder	16	.	.	.	.	.	16	0.57
Solanum dulcamara	bittersweet	.	1	2	.	.	.	3	0.57
Tilia cordata	small-leaved lime	4	.	.	.	.	.	4	0.38
Viscum album s.l.	mistletoe	.	.	9	5	3	.	17	2.49
cf. *Viscum album* s.l.	mistletoe	.	.	.	1	.	.	1	0.19
Ruderal plants									
Lapsana communis	common nipplewort	1	.	.	.	.	.	1	0.19
Ranunculus repens	creeping buttercup	.	.	3	.	.	.	3	0.19
Other									
Carex sp.	sedge	.	.	98	.	.	.	98	0.19
Centaurea sp.	knapweed	.	.	2	.	.	.	2	0.19
Chenopodium sp.	goosefoot	.	.	.	1	.	.	1	0.19
Cyperaceae	sedges	.	.	28	.	.	.	28	0.19
cf. Cyperaceae	sedges	.	.	3	.	.	.	3	0.19
Equisetum spec.	horsetail	.	.	10	.	.	.	10	0.19
Fabaceae Trifolium-Type	legume family - Trifolium Type	.	1	14	.	.	.	15	0.38
Fabaceae	legume family	1	1	.	.	.	.	2	0.38
cf. *Lotus* sp. - inflorescence	trefoil	.	.	1	.	.	.	1	0.38
Melilotus/Medicago/Trifolium	sweet clover/medick/clover	.	37	.	1	.	.	38	0.19
Pinus sp. - needle	pine	179	.	.	.	.	.	179	0.57
Poaceae	grasses	1	.	2	.	.	.	3	0.38
Solanum sp.	nightshade	2	.	1	.	.	.	3	0.57
Indeterminata - s/f	not determined	4	26	39	13	6	.	88	5.36
Indeterminata - amorphous objects	not determined	37	10	24	146	3	63	283	14.56
Indeterminata - other plant parts	not determined	185	10	23	215	3	.	436	5.75
Total		680	189	298	836	59	65	2127	
Density		8.9	1.4	1.3	2.2	0.3	0.6	1.9	

somewhat pushed back by other deciduous trees of the mixed oak forests such as oak, lime, elm and maple tree during the Atlantic period, it remained an important component of the light / bright forests and could thus also easily be collected by the Late Mesolithic population. The exploitation of hazelnuts as a food resource is well documented in other parts of Europe (see e.g. Kind 2010; Kind et al., 2012; Schlichtherle 2001; Regnell, 2011; Vaquer and Ruas, 2009). Hazelnuts can be harvested in late summer or early autumn and then prepared for consumption and/or preserved. Some authors suggest that during the Mesolithic hazelnuts were roasted before storage, others argue that they were dried instead (see Bishop et al., 2013). Accidental charring during both processes may explain the presence of charred fragments in Mesolithic deposits, including at the sites we investigated. Large accumulations of hazelnut shells were found in the Mesolithic settlements at the edge of the Duvensee bog in northern Germany (Holst 2010; Gross et al., 2019) (some of which are contemporary with those of Layer 9 in the rock shelter in Lutter) and at Siebenlinden (Kind and Beutelspacher, 2009; Kind 2010). It has been put forward that the Duvensee settlements had a function as nut-roasting places. The same could be proposed for Layer 9 in Lutter. It represents one of the richest and best preserved layers of the entire shelter occupation. It is clear that hazelnuts played an important role in the subsistence of Mesolithic hunter-gatherers. In the Early Mesolithic levels of Siebenlinden, the authors suggest that for a short period of the year, hazelnuts were as nutritious as meat (Kind and Beutelspacher, 2009). Bishop et al (2013) conclude from a review of archaeobotanical data from the Scottish Mesolithic that hazelnuts were targeted for gathering and were an important part of the diet. At Berdorf-Kalekapp 2, a rock shelter in Luxembourg, the study of hazelnut shells showed that hazelnuts accounted for less than 1% of the energy intake in the diet, in contrast to animal products, which accounted for 99% of this value, and that the role of hazelnuts was therefore merely complementary (Leesch et al., 2017). This is, however, difficult to judge, as these different types of remains have completely different taphonomic histories and abilities to preserve!

Besides hazelnuts, findings of mistletoe were rather frequent at Arconciel. Mistletoe is a hemiparasitic plant that grows on hardwoods or softwoods. Although it probably came by chance with wood or bird droppings, it could be harvested as a medicinal plant. In both sites, other edible plants, such as apples/pears or blood dogwood, are only present in small quantities. As only isolated seeds have been recovered, it is possible that they were brought in via natural processes.

It is very likely that a much wider range of plants were collected and consumed but the parts of these plants (leaves, bulbs or roots) are not usually preserved in archaeological deposits, and only rarely identified. Nevertheless, scanning electron microscopy (SEM) techniques have proved very effective in identifying archaeological parenchyma, including roots and bulbs (Kubiak-Martens 2016). These underground plant parts seem to have been of great value among the Mesolithic population due to their high carbohydrate and fat content. Evidence of starch gathering is present in Mesolithic Europe, and suggests that it was an important source of dietary energy (Kubiak-Martens 2016). On both of our investigated sites, this type of remains was encountered rather regularly, but so far not identified.

The role of plant resources in the daily diet in the rock shelters of Lutter and Arconciel is difficult to assess as only very small numbers of edible wild plant remains have been found. Is this due to their secondary and/or complementary role in the diet? Or is it due to different factors, related to both the intensity and duration of human occupation of the shelter? or to the differential preservation / different taphonomical history of plant macroremains in comparison e.g. to bones?

4.4. The question of Late Mesolithic agriculture

How exactly the earliest introduction of agriculture to central Europe took place is the subject of controversial debate. Today, we know from archaeo-genetic studies that immigrants from the areas of origin of agriculture in the Near East played a role in this process; they brought cultivated plants and domestic animals with the necessary know-how to Central Europe, which is proven archaeologically from around 5500 BCE (Soares et al., 2010). Yet, the present genetic composition of humans in Europe also shows that the indigenous substrate, i.e. the Mesolithic hunter-gatherers living here, lives on in our genes (Soares et al., 2010). How they adapted to the new sedentary way of life and economy (agriculture and animal husbandry) is largely unknown, even though there are countless theories about this, but hardly any findings (Gronenborn 2007). The expansion of the agricultural system across Europe is thought to have taken place in leaps and was marked by phases of geographical expansion and stasis (Bocquet-Appel et al., 2009). Based on the distribution of C^{14} cal. BC dates, the crossing into Central Europe around 6100–5600 represents the third leap of expansion of the early Neolithic population in a SE-NW direction. Since the 90 s of the 20th century, archaeobotanical findings have been used to demonstrate the extent to which the Mesolithic people of Central Europe were already practicing agriculture before or at least parallel to the establishment of Neolithic settlements in the mid-6th millennium BC. The idea for this comes from pollen evidence of the Cerealia type in natural/off-site sediments near archaeological sites. The oldest evidence dates back to the 7th or even 8th millennium BC., i.e. more than a millennium before the first secure evidence of domesticated plants and animals (see Erny-Rodmann et al., 1997). It could be that the first Mesolithic “attempts” to grow crops were made with imported grain (including the necessary know-how) that was traded through long-distance trade relations. From the 9th millennium BC onwards, agriculture and animal husbandry became widespread in the Near East, and in the course of the 8th and 7th millennia BC. these farming communities slowly spread to Europe (via the Balkans, and the western Mediterranean coasts: Budja 2004; Pavuk 2004). Long-distance trade relations are established in this period. This is attested, for example, by Mediterranean shells found in Central Europe (Rähle 1980), or a pintadera, a stamp made of clay originating from the eastern Mediterranean, found in the rock shelter of Arconciel - La Souche (Mauvilly et al., 2008). The existence of Mesolithic agriculture is also a subject of debate in the archaeobotanist community. Among palynologists, opinions differ. For some, isolated finds of pollen grains of the pre-Neolithic Cerealia type support the hypothesis of the existence of early agriculture, before the arrival of the first Early Neolithic communities (e.g. Erny-Rodmann et al., 1997, Tinner et al., 2007, Tinner et al., 2008). Others contest this hypothesis arguing that an absolute distinction between Cerealia pollen grains and large wild grasses is impossible and that their presence is therefore not evidence of Mesolithic agriculture (Behre 2007, 2008). In his critical evaluation of the available data and their interpretation for Central and Northern Europe, Behre (2007) concludes that as long as there are no plant macroremains - i.e. cereal grains - in Mesolithic contexts to support this hypothesis, there is no evidence for the existence of Mesolithic agriculture. Therefore, reliable and AMS-dated on-site evidence of cereal macro remains from this period is needed – which was one of the reasons for the investigations of the sites presented here. So far there are none from Central Europe – not even after the thorough sieving and analyses of the Late Mesolithic Levels in Arconciel and Lutter. In the only site comparable to the latter two, the Abri Reinhausen / Bettenroder Berg IX near Göttingen (Wolf 1994) cereal finds from the late Mesolithic layers have not been directly C^{14}-dated. Based on our experience, their dating must be questioned until a C^{14} date is available. The oldest C^{14}-dated cereal grains within the area of research orginate from two LBK sites in the Ammer Valley in SW-Germany (Lüsse and Unteres Feld); they date between 5300 and 5000 cal. BC (Krauß et al., 2020). The oldest C^{14}-dated cereal grains in Switzerland are from a site in the Valais, Sion La Planta and date between 5100 and 4700 cal. BC (6027 ± 35)(Martin 2015). We were hoping that the investigations in the rock shelters of Lutter - St. Joseph and Arconciel - La Souche would shed new light on this issue. Unfortunately, the cereal grains present in the Mesolithic levels of Arconciel and Lutter cannot support a possible pre-Neolithic agriculture in the region either, since they represent younger intrusions.

5. Conclusions

Our investigations show that the effort to demonstrate late Mesolithic plant use is very high, but without doubt possible. Since a long time it is known that Mesolithic people have used hazelnuts to a large extent. This could be corroborated by our data. In addition, other plant taxa and parts were used. The latter most likely include parenchyma remains, suggesting the processing of roots, tubers and other starchy foods. We conclude, that plants were used at a regularly basis in Mesolithic times, also in Central Europe and suggest for future research of the Mesolithic diet, the necessity to study all amorphous charred plant remains in order to expand our knowledge on these types of remains.

However, to prove cereal cultivation through on-site evidence seems extremely difficult – our investigations give hints that such cultivation is very unlikely. When investing the effort, however, such proof would theoretically be possible. For investigation only clear structures without (natural?) disturbances should be chosen. If one finds cereal remains in a Mesolithic context, virtually any remain has to be C14-AMS-dated to rule out younger intrusions. The probability of contamination is unfortunately high, as shown by the examples from Lutter and Arconciel and several others before that.

CRediT authorship contribution statement

Stefanie Jacomet: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Patricia Vandorpe:** Formal analysis, Writing – original draft, Writing – review & editing.

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References

Akeret, Ö. (2022) Archäobotanik – 8000 Jahre Umwelt- und Nutzungsgeschichte im Spiegel der Pflanzenfunde. In: F. Wegmüller, Der Abri Unterkobel bei Oberriet, Ein interdisziplinärer Blick auf 8000 Jahre Siedlungs- und Umweltgeschichte im Alpenrheintal, Archäologie im Kanton St.Gallen 3, St. Gallen 2022.

Angelin, A., Bridault, A., Jacques Leopold Brochier, J.L., Chaix, L., Chesnaux, L., Marquebielle, B., Martin, L., Nicod, P.-Y., Picavet, R., Vannieuwenhuyse, D., 2016. The First Mesolithic in the French Alps: New data from La Grande Rivoire rockshelter (Vercors range, Isere, France). Quat. Int. 423, 193–212.

Antolín, F., Steiner, B.L., Vach, W., Jacomet, S., 2015. What is a litre of sediment? Testing volume measurement techniques for wet sediment and their implications in archaeobotanical analyses at the Late Neolithic lake-dwelling site of Parkhaus Opéra (Zürich, Switzerland). J. Archaeol. Sci. 61, 36–44.

Antolin F., Natàlia Alonso, N., López, V., Pérez, G., Zapata, L. (in press) Mesolithic plant use in the Iberian Peninsula.

Arbogast, R. (avec la collaboration de Denaire, A., Doppler, T., Jacomet. S. Jeunesse, Ch., Mauvilly, M. & Schibler, J.) (2011) Lutter "Abri Saint-Joseph" (Haut Rhin). Rapport de fouille programmée. Ed. Service regional de l'Archéologie en Alsace.

Baines, J.A., Riehl, S., Conard, N., Zeidi-Kulehparcheh, M., 2015. Upper Palaeolithic archaeobotany of Ghar-e Boof cave, Iran: a case study in site disturbance and methodology. Archaeol. Anthropol. Sci. 7 (2), 245–256.

Behre, K.-E., 2007. Wo sind die Nachweise für mesolithischen Ackerbau in Mitteleuropa? Zum Diskussionsbeitrag von W. Schön und B. Gehlen in Arch. Inf. 29, 1&2, 127-128. Archäologische Informationen 30/2, 53–57.

Behre, K.-E., 2008. Comment on: "Mesolithic agriculture in Switzerland? A critical review of the evidence'' by W. Tinner, E.H. Nielsen and A.F Lotter. Quat. Sci. Rev. 27 (13-14), 1467–1468.

Bernabeu, J., Barton, C.M., Perez Ripoll, M., 2001. A Taphonomic Perspective on Neolithic Beginnings: Theory, Interpretation, and Empirical Data in the Western Mediterranean. J. Archaeol. Sci. 28 (6), 597–612.

Bishop, R.R., Church, M.J., Rowley-Conwy, P.A., 2013. Seeds, fruits and nuts in the Scottish Mesolithic. Proceed. Soc. Antiquar. Scotl. 143, 9–71.

Borojevic, K., 2011. Interpreting, dating, and reevaluating the botanical assemblage from tell Kedesh: a case study of historical contamination. J. Archaeol. Sci. 38 (4), 829–842.

Bocquet-Appel, J.-P., Naji, S., Vander Linden, M., Kozlowski, J.K., 2009. Detection of diffusion and contact zones of early farming in Europe from thespace-time distribution of 14C dates. Journal of Archaeological Science 36, 807–820.

Borić, D., French, C.A.I., Stefanović, S., Dimitrijević, V., Cristiani, E., Gurova, M., Antonović, D., Allué, E., Filipović, D., 2014. Late Mesolithic lifeways and deathways at Vlasac (Serbia). J. Field Archaeol. 39 (1), 4–31.

Bouby, L., Surmely, F., 2004. Les restes carpologiques carbonisés du site mésolithique des Baraquettes IV (Velzic, Cantal). Bul. de la Société préhistorique française, tome 101 (3), 457–462.

Budja, M., 2004. The Neolithisation of the Balkans: where in the puzzle ? In: L, A., Zvelebil, M. (Eds.), LBK Dialogues. Studies in the formation of the Linear Pottery Culture. BAR International Series, Oxford, pp. 37–48.

Clarke, D.L., 1976. Mesolithic Europe: The economic basis. In: Sieveking, G., Longworth, I.H., Wilson, K.E. (Eds.), Problems in Economic and Social Archaeology, pp. 449–481.

Colledge, S., Conolly, J., 2010. Reassessing the evidence for the cultivation of wild crops during the Younger Dryas at Tell Abu Hureyra, Syria. Environ. Archaeol. 15 (2), 124–138.

Costantini, L., 1981. Semi e carboni del mesolithico e neolitico della Grotta dell'Uzzo, Trapani. Quaternaria 23, 233–247.

Costantini, L., Piperno, M. and Tusa, S. (1987) La néolithisation de la Sicile occidentale d'après des résultats des fouilles à la grotte de l'Uzzo (Trapani). In: Premières communautés paysannes en méditerranée occidentale. Actes du colloque international du C.N.R.S., Montpellier, 26-29 avril 1983.

Cristiani, E., Radini, A., Edinborough, M., Borić, D., 2016. Dental calculus reveals Mesolithic foragers in the Balkans consumed domesticated plant foods. PNAS 113 (37), 10298–10303.

Crotti, P. (1993) Spätpaläolithikum und Mesolithikum in der Schweiz: die letzten Jäger. In: Die Schweiz vom Paläolithikum bis zum frühen Mittelalter SPM. Vom Neandertaler bis zum Karl dem Grossen. Paläolithikum und Mesolithikum. Basel, Verlag Schweizerische Gesellschaft für Ur- und Frühgeschichte.

Dark, P., 2004. Plant Remains as Indicators of Seasonality of Site-Use in the Mesolithic Period. Environ.Archaeol. 9 (1), 39–45.

Divišová, M., Šída, P., 2015. Plant use in the Mesolithic period. Archaeobotanical data from the Czech Republic in a European context – a review. Interdisciplinaria Archaeol. VI (1/2015), 95–106.

Erny-Rodmann, C., Gross-Klee, E., Haas, J.N., Jacomet, S., Zoller, H., 1997. Früher "human impact" und Ackerbau im Uebergangsbereich Spätmesolithikum-Frühneolithikum im schweizerischen Mittelland. Jahrbuch Schweizerisch. Gesellschaft für Ur- Frühgeschichte 80, 27–56.

Filipović, D., Allué, E.A., Borić, D., 2010. "Integrated carpological and anthracological analysis of plant record from the mesolithic site of Vlasac, Serbia." Glasnik Srpskog Arh. Društva. J. Serb. Archaeol. Soc. 26, 145–161.

Gregg, S. A. (1993). Die Samen, Nüsse und Früchte. In: Jochim, M. (ed). Henauhof Nordwest - ein mittelsteinzeitlicher Lagerplatz am Federsee. Materialhefte zur Vor- und Frühgeschichte in Baden-Württemberg. Stuttgart, Konrad Theiss Verlag, 19, 53-71.

Gronenborn, D., 2007. Beyond the models: "Neolithisation" in Central Europe. Proceed. Br. Acad. 144, 73–98.

Groß, D., Lübke, H., Schmölcke, U., Zanon, M., 2019. Early Mesolithic activities at ancient Lake Duvensee, northern Germany. The Holocene 29 (2), 197–208.

Hansen, J.M., 1991. The Palaeoethnobotany of Franchthi Cave, Greece. Excavations at Franchthi Cave. Bloomington, Greece 7.

Hather, J. G. and Mason, S. L. R. (2002) Introduction: some issues in the archaeobotany of hunter-gatherers. In: Mason, S. L. R. und Hather, J. G. (Hrsg.) Hunter-Gatherer Archaeobotany: perspectives from the northern temperate zone. London, 1-14.

Heinz, C., Ruas, M.-P., Vaquer, J., 1992. La grotte de l'Abeurador (Fölines-Minervois, Hérault): paléoécologie d'après l'anthracologie et la carpologie. Bull. soc. bot. Fr. 139/Actual bot. 2/3/4, 465–482.

Hillman, G.C., 2000. Abu Hureyra I: The Epipalaeolithic. In: Moore, A.M.T., Hillman, G. C., Legge, A.J. (Eds.), Village on the Euphrates. From foraging to farming at AbuHureyra. Oxford University Press, Oxford, pp. 327–399.

Holst, D. (2007) Subsistenz und Landschaftsnutzung im Frühmesolithikum: Nussröstplätze am Düvensee. PhD. Mainz, 328.

Holst, D., 2010. Hazelnut economy of early Holocene hunter-gatherers: a case study from Mesolithic Duvensee, northern Germany. J. Archaeol. Sci. 37 (11), 2871–2880.

Hosch, S., Zibulski, P., 2003. The influence of inconsistent wet-sieving procedures on the macroremains concentration in waterlogged sediments. J. Archaeol. Sci. 30, 849–857.

Jacomet, S. (2013) Archaeobotany: Analyses of plant remains from waterlogged archaeological sites. In: F. Menotti, A. O'Sullivan (ed.), The Oxford Handbook of wetland archaeology (Oxford 2013), 497– 514.

Jacomet, S. and Martinoli, D. (2008) Premiers résultats concernant les macrorestes botaniques. In: Mauvilly, Michel avec la collaboration de Luc Dafflon et Fiona McCullough, L'abri mésolithique d'Arconciel/La Souche: bilan des recherches 2003-2007. Cahier d'Archéologie Fribourgeoise 10, 63-64.

Jahns, S. Wolters, S. (2021) Mesolithic and Early Neolithic in Brandenburg from the Botanical Point of View. In: Schier, W., Orschiedt, J., Stäuble, H., Liebermann, C. (eds) Mesolithikum oder Neolithikum? Auf den Spuren später Wildbeuter. Berlin Studies of the Ancient World 72, 205-228.

Jeunesse, C., Arbogast, R.-M., Denaire, A., Doppler, T., Jacomet, S., Mauvilly, M., Schibler, J., 2014. L'abri Saint-Joseph à Lutter : 9000 ans d'histoire du Jura alsacien. Annuaire de la Société d'Histoire du Sundgau 13–44.

Jochim, M., 1993. Henauhof Nordwest - ein mittelsteinzeitlicher Lagerplatz am Federsee. Materialhefte zur Vor- und Frühgeschichte in. Baden-Württemberg.

Kalis, A. J., Kubiak-Martens L., Meurers-Balke J. (2015). Archäobotanische Untersuchungen am mesolithischen Fundplatz Dąbki 9. In: J. Kabaciński, S. Hartz, D. C. M. Raemaekers and T. Terberger (eds) The Dąbki site in Pomerania and the neolithisation of the North European Lowlands [c. 5000-3000 cal B.C.] = Der Fundplatz Dąbki in Pommern und die Neolithisierung der nordeuropäischen Tiefebene (ca. 5000-3000 cal B.C.). Rahden, Verlag Marie Leidorf GmbH 31-50.

Kind, C.-J., 1997. Die letzten Wildbeuter. Henauhorf Nord II und das Endmesolithikum in Baden-Württemberg. Materialhefte zur Archäologie in Baden-Württemberg 39, Stuttgart.

Kind, C.-J., 2003. Das Mesolithikum in der Talaue des Neckars – Die Fundstellen von Rottenburg Siebenlinden 1 und 3. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg 88. Konrad Theiss Verlag, Stuttgart.

Kind, C.-J., Beutelspacher, T., David, E., Stephan, E., 2012. Das Mesolithikum in der Talaue 2. Die Fundstreuungen von Siebenlinden 3, 4 und 5. Forschungen und Berichte zur Vor und Frühgeschichte in Baden-Württemberg. Konrad Theiss Verlag, Stuttgart.

Kind, C.-J., 2010. Jenseits des Flusses - mesolithische Lagerplätze in Siebenlinden 3, 4 und 5 (Rottenburg am Neckar, Lkr. Tübingen). Archäologisch. Korrespondenzbl 40/ 4, 467–486.

Kind, C.-J., Beutelspacher, T. (2009) Haselnüsse am Fluss. Ein spezialisierter Lagerplatz aus dem frühmesolithischen Horizont IV von Siebenlinden (Rottenburg a.N., Kreis Tübingen). In: Biel, J., Heiligmann, J. und Krausse, D. (Hrsg.) Landesarchäologie: Festschrift für Dieter Planck zum 65. Geburtstag. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg. Stuttgart, 41-60.

Koch, I., Löhr, H., Gehlen, B., Rethemeyer, J., Tegtmeier U., Zerl, T. (2017) Mittelsteinzeitliche Fundkomplexe des 9. Jahrtausends im Bezirk Trier (Rheinland-Pfalz): Chronologischer Kontext, Rohstoffversorgung und Aktivitätsräume. Archäologische Informationen 40, 2017, 161-200.

Kotzamani, G., Livarda, A., 2018. People and plant entanglements at the dawn of agricultural practice in Greece. An analysis of the Mesolithic and early Neolithic archaeobotanical remains. Quat. Int. 496, 80–101.

Krauß, R., Bofinger, Jörg, Weninger, B., 2020. Chronology of Early Neolithic sites in the Ammer Valley, West of Tübingen (SW-Germany). Quat. Int. 560-561, 273–285.

Kreuz, A., Schäfer, E., 2014. Archäobotanisches Datenbankprogramm ArboDat 2013 Wiesbaden. Hessen Archäologie.
Kubiak-Martens, L., 1996. Evidence for possible use of plant foods in Palaeolithic and Mesolithic diet from the site of Calowanie in the central part of the Polish Plain. Veget. History Archaeobot. 5 (1-2), 33–38.
Kubiak-Martens, L. (1999) The plant food component of the diet at the late Mesolithic (Ertebölle) settlement at Tybrind Vig, Denmark. In: Proceedings of the 11th IWGP Symposium Toulouse 1998. Vegetation History and Archaeobotany 8 (1-2), 117-127.
Kubiak-Martens, L., 2002. New evidence for the use of root foods in pre-agrarian subsistence recovered from the last Mesolithic site at Halsskov, Danmark. Vegetat. Hist. Archaeobot. 11 (1-2), 23–31.
Kubiak-Martens, L. (2016) Scanning electron microscopy and starchy food in Mesolithic Europe: the importance of roots and tubers in Mesolithic diet. In: Hardy, K., Kubiak-Martens, L. (eds) Wild harvest: Plants in the hominin and pre-agrarian human worlds, Oxford, 113-134.
Kubiak-Martens, L., Tobolski, K., 2014. Late Pleistocene and Early Holocene Vegetation History and Use of Plant Foods in the Middle Vistula River Valley at Całowanie (Poland). In: Schild, R. (Ed.), Całowanie a Final Paleolithic and Early Mesolithic site on an island in the ancient Vistula Chanel. Warsaw: Institute of Archaeology & Ethnology. Polish Academy of Sciences, pp. 33–348.
Kubiak-Martens, L., Kooistra, L. I. and Verbruggen, F. 2015. Archaeobotany: landscape reconstruction and plant food subsistence economy on a meso and microscale. In Moree, J. M. and Sier, M. M. (eds), Interdisciplinary Archaeological Research Program Maasvlakte 2, Rotterdam, Part 1, Twenty metres deep! The Mesolithic period at the Yangtze Harbour site – Rotterdam Maasvlakte, the Netherlands. Early Holocene landscape development and habitation. Rotterdam: BOORrapporten 566, 223–286.
Lang, G. (1994) Quartäre Vegetationsgeschichte Europas. Jena.
Leesch, D., Schoch, W.H., Fabre, M., 2017. Les occupations mésolithiques des abris-sous-roche de Berdorf-Kalekapp 2 (Grand-Duché de Luxembourg). Centre national de recherche archéologique, Luxembourg.
Leuzinger, U., Affolter, J., 2016. Der frühmesolithische Abri Berglibalm im Bisistal, Gemeinde Muotathal SZ. Jahrbuch Archäol. Schweiz 99, 7–26.
Leuzinger, U., Jagher, R., Imhof, W., Affolter, J., Müller, W., Schoch, W., Haas, J.N., Hajdas, I., 2020. The Mesolithic Berglibalm Rock Shelter (Muotathal, Ct. Schwyz/CH). Archäolog. Korrespondenzb. 50, 305–322.
Marinova, E., Filipović, D., Obradović, D., Allué, E., 2013. Wild Plant Resources and Land Use in Mesolithic and Early Neolithic South-East Europe. Archaeobotanical Evidence from the Danube Catchment of Bulgaria andSerbia. Offa 69 (70), 467–478.
Martin, L., Delhon, C., Thiébault, S., Pelletier, D., 2012. Plant exploitation and diet in altitude during Mesolithic and Neolithic: Archaeobotanical analysis from a hunting camp in the Chartreuse massif (l'Aulp-du-Seuil, Isère, France). Rev. Palaeobot. Palynol. 185, 26–34.
Martin, L., 2015. Plant economy and territory exploitation in the Alps during the Neolithic (5000–4200 cal BC): first results of archaeobotanical studies in the Valais (Switzerland). Vegetat. History Archaeobot. 24, 63–73.
Martínez-Grau, H., Jagher, R., Oms, F.X., Barceló, J.A., Pardo-Gordó, S. and Antolín, F. (2020) Global processes, regional dynamics| Radiocarbon data as a proxy for social dynamics at the end of the Mesolithic and during the Early Neolithic in the NW of the Mediterranean and Switzerland (c. 6200–4600 cal BC). Documenta Praehistorica XLVII, 170-191.
Martinoli, D., Jacomet, S., (2008) Etude carpologique à Cornaux/Prés du Chêne (NE) : test de potentialité. Rapport non-publié.
Mason, S., Boroneant, V., Bonsall, C., 1996. Plant remains from Schela Cladovei, Romania: a preliminary note. Mesol. Miscell. 17 (2), 1–14.
Mason, S., Hather, J. G. and Hillman, G. C. (2002) The archaeobotany of European hunter-gatherers: some preliminary investigations. In: Mason, S. L. R. and Hather, J. G. (Hrsg.) Hunter-Gatherer Archaeobotany. Perspectives from the northern temperate zone. London, 188-196.
Mason, S.L.R., Hather, J.G., Hillman, G.C., 1994. Preliminary investigation of the plant macro-remains from Dolní Vestonice II, and its implications for the role of plant foods in Palaeolithic and Mesolithic Europe. Antiquity 68, 48–57.
Maury, J., Frayssenge, J.H., 1990. Des restes de légumineuses dans un niveau sauveterrien de l'Abri des Usclades (Nant, Aveyron). Bull. Soc. Préhistor. Française 87, 72–73.
Mauvilly, M., 2008. L'abri mésolithique d'Arconciel/La Souche : bilan des recherches 2003–2007. Cahiers d'Archéol. Fribourg. 10, 44–75.
Mauvilly, M., Jeunesse, C., Doppler, T., 2008. Ein Tonstempel aus der spätmesolithischen Fundstelle von Arconciel/La Souche (Kanton Freiburg, Schweiz). Quartär 55, 151–157.
Milner, N., Lane, P., Taylor, B., Conneller, C., Schadla-Hall, T., 2011. Star Carr in a Postglacial Lakescape: 60 Years of Research. J. Wetland archaeol. 11 (1), 1–19.
Nielsen, E.H., 1996. Untersuchung einer alt- und mittelsteinzeitlichen Fundstelle in Wauwil-Obermoos. Heimatk. Wiggertal 54 (1996), 47–65.
Out, W., 2009. Sowing the seed? Human impact and plant subsistence in Dutch wetlands during the Late Mesolithic and Early and Middle Neolithic (5500–3400 cal BC). Archaeological Studies Leiden University, Leiden.
Pavuk, J. (2004) Early Linear Pottery Culture in Slovakia and the neolithisation of central Europe. In: A., L. and M., Z. (Hrsg.) LBK Dialogues. Studies in the formation of the Linear Pottery Culture. BAR International Series 1304. Oxford, 71-82.
Pelling, R., Campbell, G., Carruthers, W., Hunter, K., Marshall, P., 2015. Exploring contamination (intrusion and residuality) in the archaeobotanical record: case studies from central and southern England. Vegetat. Hist. Archaeobot. 24 (1), 85–99.
Perry, D., 2002. Preliminary results of an archaeobotanical analysis of Mesolithic sites in the Veenkolonien, Province of Groningen, the Netherlands. In: Mason, S.L.R., Hather, J.G. (Eds.), Hunter-Gatherer Archaeobotany: perspectives from the northern temperate zone. Institute of Archaeology, University College London, . London, pp. 108–116.
Pryor, A.J., Steele, M., Jones, M.K., Svoboda, J., Beresford-Jones, D.G., et al., 2013. Plant foods in the Upper Palaeolithic at Dolni Věstonice? Parenchyma redux. Antiquity 87 (338), 971–984.
Rähle, W. (1980) Schmuckschnecken aus mesolithischen Kulturschichten Süddeutschlands und ihre Herkunft. In: Taute, W. (Hrsg.) Das Mesolithikum in Süddeutschland. Teil 2 : Naturwissenschaftliche Untersuchungen. Tübinger Monographien zur Urgeschichte 5 / 2. Tübingen, 163-168.
Regnell, M., 2011. Plant subsistence and environment at the Mesolithic site Tagerup, southern Sweden: new insights on the "Nut Age". Vege. Hist. Archaeobot. 21 (1), 1–16.
Regnéll, M. (1998) Archaeobotanical finds from the Stone Age of the Nordic countries. A catalogue of plant remains from archaeological contexts. Lunqua Report 36.
Rösch, M. (2000) Pflanzenreste. In: Kieselbach, P., Kind, C.-J., Miller, A. M. and Richter, D. (Hrsg.) Siebenlinden 2. Ein mesolithischer Lagerplatz bei Rottenburg am Neckar, Kreis Tübingen. Materialhefte zur Archäologie in Baden-Württemberg 51. Stuttgart, 59-63.
Salavert, A., Gouriveau, E., Messager, E., Lebreton, V., Kiosak, D., 2020. Multi-proxy Archaeobotanical Analysis from Mesolithic and Early Neolithic Sites in South-west Ukraine. Environ. Archaeol. 26 (3), 349–362. https://doi.org/10.1080/14614103.2020.1746879.
Savard, M., 2000. Etude de l'assemblage carpologique de la Baume de Fontbrégoua (Var) du Paléeolithique final au Chasséen récent. Mémoire du DEA multisceaux Environnement et Archéologie, Université de Paris 1. Panthéon-Sorbonne et de Paris X, Nanterre.
Schlichtherle, H., 2001. Eine mesolithische Haselnusslage in der Station Taubried II im südlichen Federseemoor, 2. In: Gehlen, B., Heinen, M., Tillmann, A. (Eds.), Zeit-Räume. Gedenkschrift für Wolfgang Taute. Archäologische Berichte, Bonn, pp. 613–618.
Schlichtherle, H., 1988. Henauhof-Nord, ein mesolithischer Lagerplatz im Federseemoor, Stadt Bad Buchau, Kreis Biberach. Archäolog. Ausgrabung. Baden-Württemb. 28–34.
Soares, P., Achilli, A., Semino, O., Davies, W., Macaulay, V., Bandelt, H.-Jürgen., Torroni, A., Richards, M.B., 2010. The archaeogenetics of Europe. Curr. Biol. 20 (4), R174–R183.
Sobkowiak-Tabaka, I., Pawłowski, D., Milecka, K., Kubiak-Martens, L., Kostecki, R., Janczak-Kostecka, B., Goslar, T., Ratajczak-Szczerba, M., 2020. Multi-proxy records of Mesolithic activity in the Lubuskie Lakeland (western Poland). Vegetat. Hist. Archaeobot. 29, 153–171.
Taute, W. (1975) Ausgrabungen zum Spätpaläolithikum und Mesolithikum in Süddeutschland. In: K. Böhner (ed.), Ausgrabungen in Deutschland. Monografien des Römisch-Germanischen Zentralmuseums 1,1. Mainz, 64–73.
Tinner, W., Nielsen, E.H., Lotter, André.F., 2007. Mesolithic agriculture in Switzerland? A critical review of the evidence. Quat. Sci. Rev. 26 (9-10), 1416–1431.
Tinner, W., Nielsen, E.H., Lotter, André.F., 2008. Evidence for Late Mesolithic agriculture? A reply to Karl-Ernst Behre. Quat. Sci. Rev. 27 (13-14), 1468–1470.
Toulemonde, F. (unpublished) Rapport d'étude carpologique du site de Champigny « Le Mont-Saint-Pierre (Marne) 2017, unpublished report.
Vandorpe, P., Jacomet, S., 2007. Comparing different pre-treatment methods for strongly compacted organic sediments prior to wet-sieving: a case study on Roman waterlogged deposits. Environ. Archaeol. 12 (2), 207–214.
Vaquer, J., Ruas, M.-P., 2009. La grotte de l'Abeurador Félines-Minervois (Hérault): occupations humaines et environnement du Tardiglaciaire à l'Holocène. In: De Méditerranée et d'ailleurs... Mélanges offerts à Jean Guilaine. Archives d'Écologie Préhistorique, Toulouse, p. 853.
Verjux (2017) Les structures en creux au Mésolithique L'hypothèse du stockage enterré de fruits à coque. In: Achard-Corompt, N., Ghesquière, E., Riquier, V. (eds) Actes de la séance de la Société préhistorique française de Châlons-en-Champagne (29-30 mars 2016), 155-171.
Vermeersch, P.M., 1989. Ten Years' Research on the Mesolithic of the Belgian Lowland: Results and Prospects. In: Bonsall, C. (Ed.), The Mesolithic in Europe. John Donald Publisher, Edinburgh, pp. 284–290.
Weiss, E., Kislev, M.E., Simchoni, O., Nadel, D., Tschauner, H., 2008. Plant-food preparation area on an Upper Palaeolithic brush hut floor at Ohalo II, Israel. J. Archaeol. Sci. 35, 2400–2414.
Wegmüller, F., Hajdas, I., 2022. Der Abri Unterkobel bei Oberriet, Ein interdisziplinärer Blick auf 8000 Jahre Siedlungs- und Umweltgeschichte im Alpenrheintal., 3. Archäologie im Kanton St.Gallen, St. Gallen.
Wolf G. (1994) Paläo-ethnobotanische Befunde zu den Abris aus dem Buntsandsteingebiet im Landkreis Göttingen. In: Grote K. (ed.) Die Abris im südlichen Leinebergland bei Göttingen. Archäologische Befunde zum Leben unter Felsschutzdächern in urgeschichtlicher Zeit. Teil II: Naturwissenschaftlicher Teil. Oldenburg, 161-173.
Zapata, L., Cava, A., Iriarte, M.J., Barybar, J.P., Rua, C., 2002. Mesolithic plant use in the western Pyrenees: implications for vegetation change, use of food and human diet. Hunter-Gatherer Archaeobotany, London, pp. 96–107.
Zvelebil, M., 1994. Plant use in the mesolithic and its role in the transition to farming. Proc. Prehist. Soc 60 (1), 35–74.