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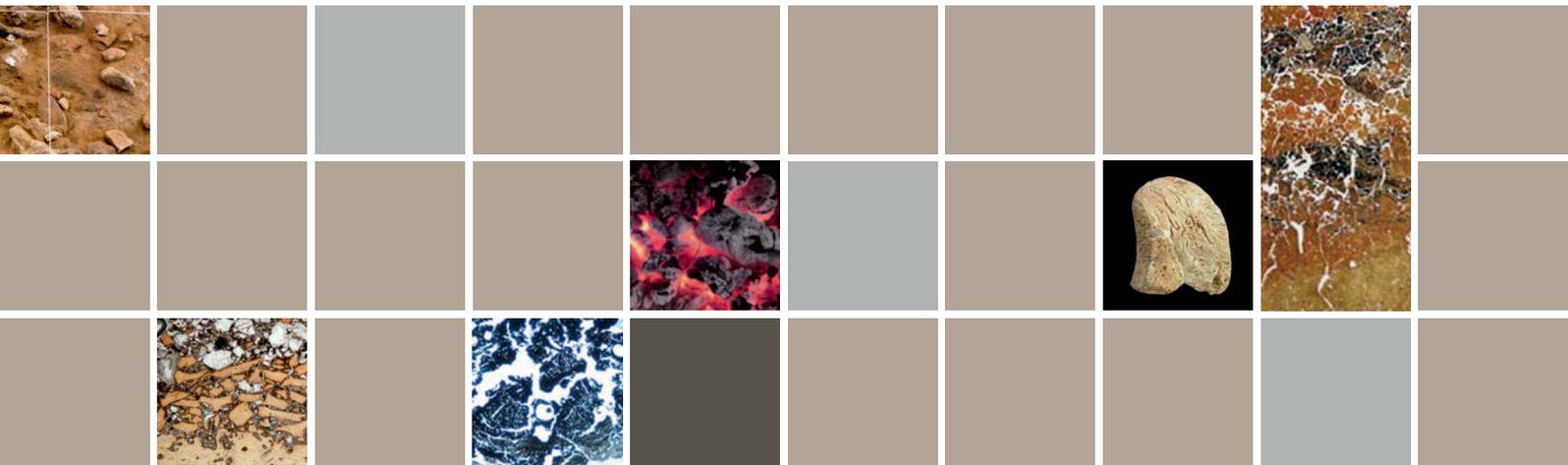
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**THE TAPHONOMY OF BURNED ORGANIC RESIDUES AND
COMBUSTION FEATURES IN ARCHAEOLOGICAL CONTEXTS**



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CARBONIZATION, PRESERVATION AND DEFORMATION OF CARPOLOGICAL REMAINS

Marie-Pierre RUAS & Laurent BOUBY

Abstract

In archaeological sites in temperate climates and with aerobic conditions, carbonized seeds represent the majority of preserved carpological remains. Among these, cereals, legumes and certain fruits are the most frequent. In this paper, we present a selection of experiments concerning the effects of carbonization on the deformation of seeds and fruits and on the differential preservation of carpological assemblages. These experiments explored the influence of parameters such as temperature, heating duration, oxidizing or reducing conditions and the initial state of the seeds in on the modifications of their forms and dimensions. They were conducted on hulled or naked caryopses, seeds of pea, apple and wild and cultivated grape seeds. Other experiments focused on the rapidity of destruction of the anatomical parts of ripe cereals (stem, rachis, glumes, caryopses) and acorns (casings, pericarps, cotyledons), and of the seeds of various wild or cultivated plants according to their physical and biological constitution. The results allow us to evaluate the taphonomic biases created by carbonization, which are detrimental to the specific identification of seeds and the interpretation of archaeological assemblages.

Keywords: seeds, carpological assemblages, preservation, deformation, experimentation, diagnosis, morphometry, cereals, legumes, grape, acorn

Introduction

Carpological remains seeds, fruits, tubers, cereal ear elements, etc. are characterized by a diversity of forms, dimensions and anatomical and chemical compositions. Their preservation in archeological sites is determined by both their state at the moment of deposition and the physical and chemical conditions of the context in which they are buried. The anaerobic conditions of waterlogged sites and contexts often preserve plant remains in a sub-fossil, humid (saturated) state. In dry sites and contexts, in temperate climates, aerobic microorganisms degrade these types of remains if they are not fossilized by carbonization or mineralization. Carbonized seeds, which are the most often preserved in these sites, have constituted the basis for the study of the origins and diffusion of cultivated plants (Zohary & Hopf, 2000).

Palethnobotanical studies conducted at sites in arid environments in the Near East and in temperate environments in Europe have shown that the carbonization of seeds can have several causes: the use of agricultural residues as a combustible material; the use of a combustion structure in the transformation or cleaning of plants (crop processing, alimentary preparation, combustible) or habitat, storage or cultivation (refuse burning, sterilization of silos, burning of vegetation) zones, or; accidental fires in occupation zones (Knörzer, 1971; Hillman, 1981; Miller, 1996; Charles, 1998; Van der Veen, 2006). Carpological studies indicate that on a site where seeds are preserved in these three states, some categories of plants are rarely present in a carbonized state: the seeds of green vegetables, spices and fruits with pits or pips (seeds). The majority of carbonized assemblages are thus composed of cereals, legumes and a few shelled fruits (Green, 1979; Ruas, 1992, Ruas *et al.*, 2006). The strictest spectra of carbonized assemblages include the plants that are processed for consumption through the use of a heat source, or those whose easily stored seeds (farinaceous seeds, shelled fruits) are exposed to fires in habitat zones (Van der Veen, 2006). Meanwhile, cereals and legumes also constitute the basis of vegetal productions in preindustrial European societies.

In this paper, we present a selection of studies that address the taphonomic effects of carbonization on the deformation

of seeds and the composition of carpological assemblages. In addition to these experiments, two ongoing projects concerning grape seeds (Bouby & Terral, unpublished) and acorns (Bouby & Ruas, unpublished) are discussed.

Deformation of seeds by carbonization

Carbonization results in modifications to the form and size of seeds that archeobotanists have known for a long time (Helbaek, 1952; Hopf, 1955 cited par Renfrew, 1973, 9-15). These modifications must thus be taken into account in all morphometric analyses and can constitute a serious handicap for taxonomic identifications, particularly at the infra-specific level, in the distinction between cultivated and wild forms of the same species, for example.

The analysis of the effects of carbonization is essentially addressed through experimentation. The first experimental reproductions in laboratory muffle furnaces were realized in the 1950's on apples (Helbaek, 1952 cited by Renfrew, 1973) and in the 1970's on grape seeds (Logothetis, 1970) and cereal caryopses (Renfrew, 1973). Since the 1990's, researchers have attempted to vary parameters such as temperature, heating duration, oxygen intake, the humidity of seeds at the beginning of the experiment and the taxon studied, in order to better understand the influence of the conditions of carbonization on modifications to the configuration of seeds.

The experiments conducted with grape seeds by H. Smith and G. Jones (1990) are representative of this type of approach (Mangafa & Kotsakis, 1996; Bouby *et al.*, 2006). Grape constitute a favorable research topic since the distinction between wild grape seeds (*Vitis vinifera* subsp. *sylvestris*) and cultivated grape seeds (*V. vinifera* subsp. *Vinifera*)—and thus the dating of the beginnings of viticulture in a given region—are generally based on morphometric characteristics. Wild grape seeds are usually small, with a globular to cordiform shape and have a short point, while domestic grape seeds are generally bigger, ovoid to pyriform and have a long point (Levadoux, 1956) (fig. 1A, 1B).

The reduction in size is accompanied by a deformation; the retraction and carbonization variably affect the dimensions of the seed (fig. 2). The seeds tend to take on a more spherical



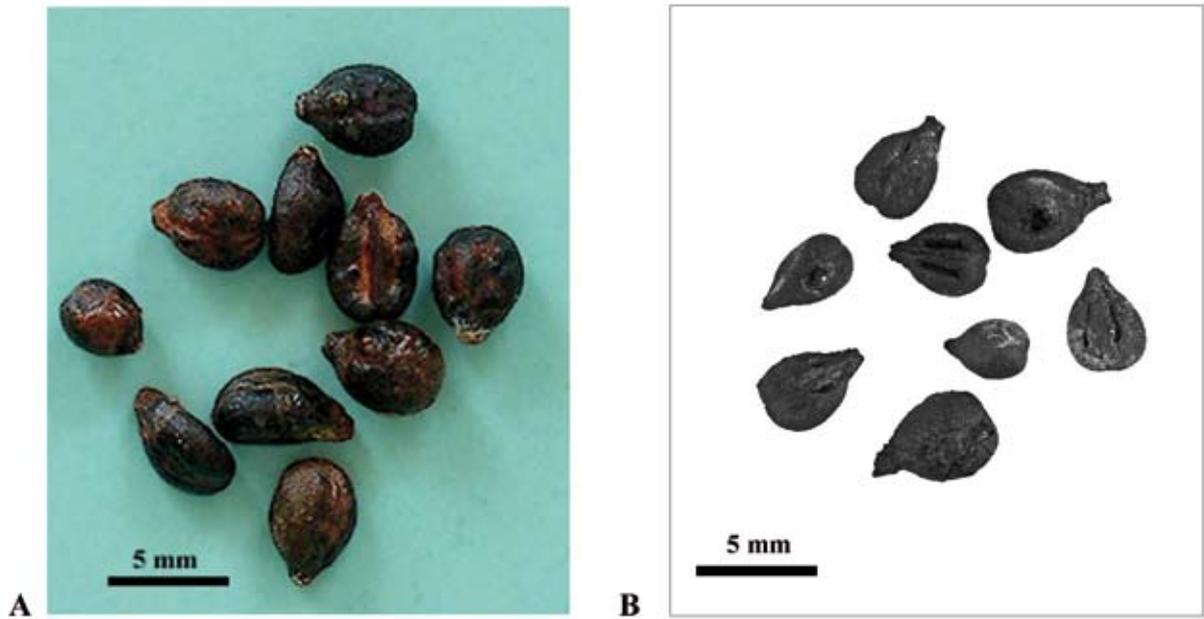


Fig. 1 : Modern fresh seeds of wild grapevines (*Vitis vinifera* subsp. *sylvestris*), Grésigne Forest (Tarn) (Photo L. Bouby); B – Carbonized seeds of cultivated/wild grapevines (*Vitis vinifera* subsp. *vinifera*) from the site of Castellu (Corte, Haute-Corse), 5th to 4th centuries. The assemblage includes cultivated seeds with a pronounced point and elongated body and wild seeds with a small point and rounded body (Photo M.-P. Ruas).

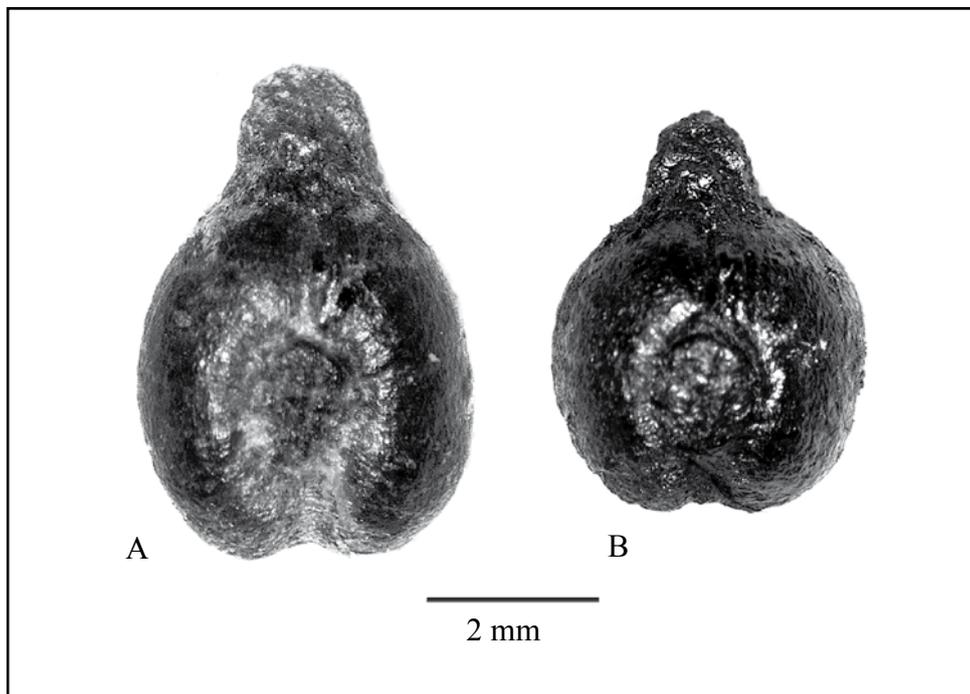


Fig. 2 : Effect of carbonization on a cultivated grape seed (*Vitis vinifera* subsp. *vinifera*), « Roussanne » cultivar (Photos L. Bouby).

A - before carbonization;

B - after carbonization at 350°C in an oxidizing atmosphere for 30 minutes. The carbonization resulted in a longitudinal retraction (especially the point) and a dorsal-ventral swelling of the seed.



form, which makes that of cultivated grapes more like that of the wild morphotype. These modifications also depend on the conditions of carbonization. Temperature is the principal parameter: the higher the temperature, the greater the deformation. The influence of oxygen intake and the heating duration is moderate. The initial humidity level of the seeds does not have a significant effect, except perhaps at high temperatures (Smith & Jones, 1990; Mangafa & Kotsakis, 1996; Bouby *et al.*, 2006). These experiments show that use of a reference base of wild and modern cultivated seeds allows their attribution to one or the other of the sub-species with a satisfying degree of precision even after carbonization (Mangafa & Kotsakis, 1996).

The results of similar studies of wheat are now available (*Triticum aestivum* & *T. dicoccum*) (Braadbaart *et al.*, 2004 ; Braadbaart & Van Bergen, 2005; Braadbaart, 2008). They also show a general reduction in size of the caryopses; their length is further reduced as the temperature increases. This occurs independently of the width, which until 300 °C, tends to augment, after which it diminishes at higher temperatures. As a result, the form index, expressed simply as the length/width ratio of the seed, varies according to the temperature. A similar observation was made for pea seeds (*Pisum sativum*) (Kislev & Rosenzweig, 1991; Braadbaart & Van Bergen, 2005).

The modifications of the form and dimensions of wheat also vary according to whether the caryopses are covered by hulls or not, particularly for emmer wheat (*T. dicoccum*), whose glumes are more robust and adhere more strongly to the seed than those of naked wheat.

The experimental results also reveal a few elements concerning the conditions of carbonization, which contribute to our understanding of the processes by which the fossil assemblage was constituted. The experiments conducted with wheat show that protrusions are produced on the surface of the caryopses, especially when the temperature rises rapidly. But as Braadbaart (2008) points out, this relationship has not been verified at high temperatures (600 °C) and the presence of such protrusions is not mentioned in the archeobotanical literature.

According to experiments realized with *Panicum miliaceum* (Lundström-Baudais *et al.*, 2002), a lateral fold appears only on the caryopses carbonized in their glumellae and the apex of some of them take on a pointed form. These types of stigmata are not present on seeds carbonized without a hull. Unfortunately, they seem to be observable on hulled grains within only a very small temperature range, between 210 °C and 230 °C. No experiments have been realized at temperatures over 250 °C.

Effects of carbonization on carpological assemblages

Other studies have addressed the biases created by differential destructions caused by carbonization within carpological assemblages, relative to their initial composition (Boardman & Jones, 1990; Van der Veen & Jones, 2006). Most concerned cereal assemblages that are probably the residues of crop processing activities. Some address the variations of assemblage compositions preserved on the floors of domestic units (Gustafsson, 2000; Guarino & Sciarrillo, 2004).

Experimental carbonizations of whole cereal ears and hulled and dehusked grains analyzed the resistance of the different elements (rachis, glumes, glumellae, seeds: fig. 3) at different temperatures and exposure duration (Bowman, 1966; Jenkinson, 1976 cited by Boardman & Jones, 1990). They demonstrated the significant effects of two factors on the differential destruction of anatomical parts. While their color becomes only slightly browner at low temperatures, higher temperatures carbonize the seeds and more rapidly destroy the rachis and glumes. A. Bowman (1966) observed that with Einkorn wheat (*Triticum monococcum*), the hulls are carbonized at higher temperatures than are the seeds (fig. 4A, 4B).

D. Wilson (1984) and T. Märkle & M. Rösch (2008) studied the seeds of different wild and cultivated species according to their chemical composition and reserves (carbohydrates, lipids), as well as their dimensions and form (compact, flat). Their study included the oleaginous seeds of flax (*Linum usitatissimum*), poppy (*Papaver somniferum*) and crucifera, small millet (*Setaria italica*



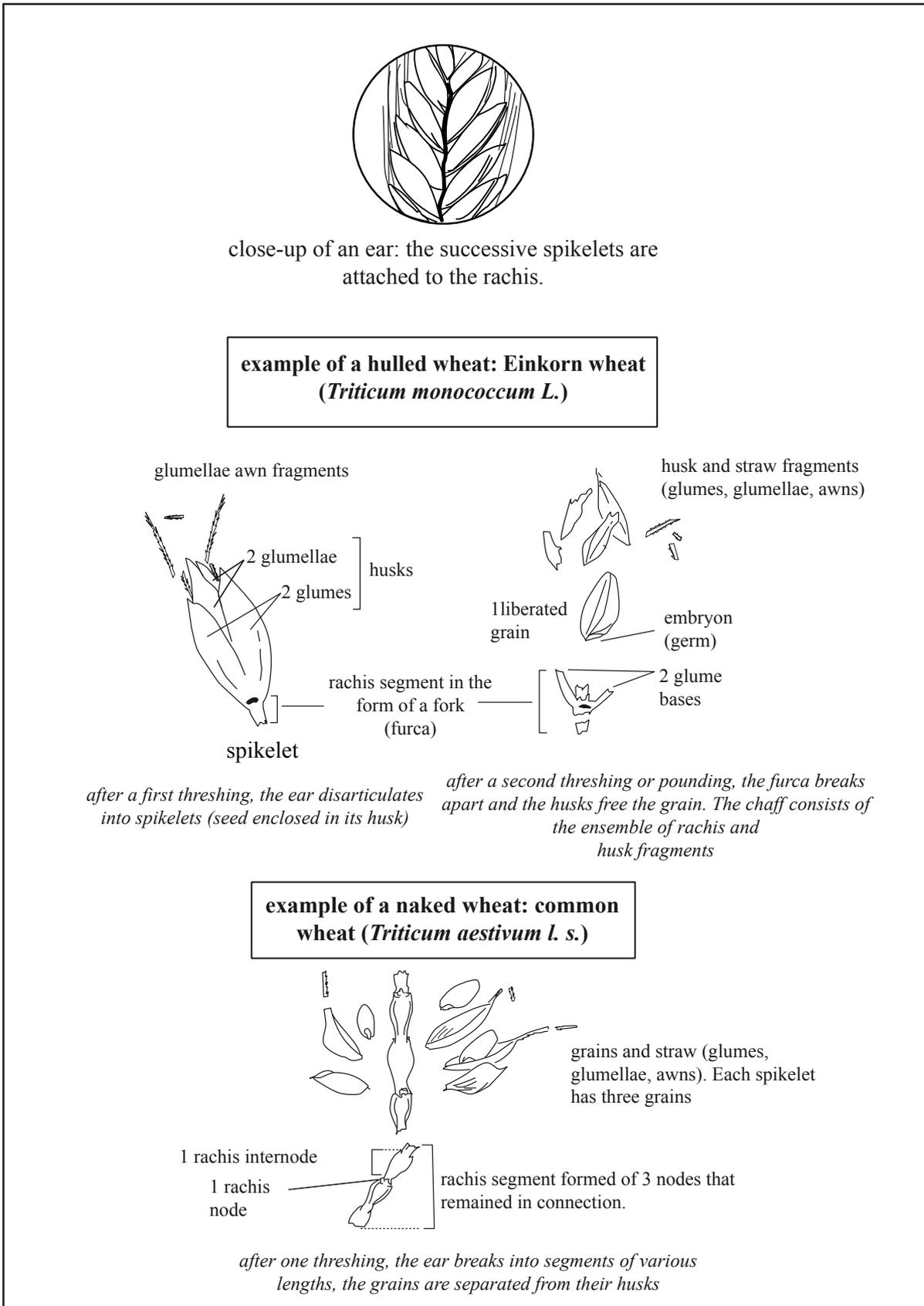


Fig. 3 : Composition of hulled and non hulled cereal ears. The threshing and dehusking operations separate the seeds from the chaff (hulls, barbs, rachis). Depending on the combustion conditions, these anatomical elements are destroyed at variable rates or are maintained in a carbonized state. (drawing M.-P. Ruas after Ruas 2002 modified).



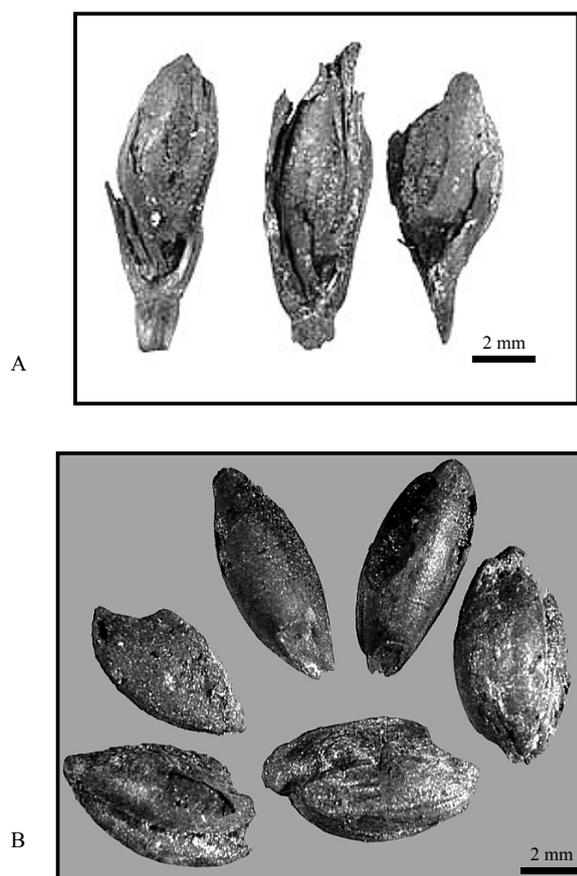


Fig. 4 : Carbonized remains of Einkorn wheat (*Triticum monococcum*), La Gravette granary (Isle-Jourdain, Gers), 11th century (photos M.-P. Ruas).

A – Carbonized spikelets: the bases of glumes (furcas), the glumellae and the seeds are preserved.

B – Seeds without hulls following carbonization.

et *Panicum miliaceum*) and several weed species. The seeds rich in lipids tended to burst when heated and were less resistant than the seeds with amyloacea reserves. Compact legume seeds covered with a thick tegument burn slower than flat seeds (flax) or the smallest seeds (weeds, millets). These studies permitted evaluations of the loss of different taxa, which affect the assemblages at the moment of carbonization.

The degree of humidity of the seeds (Wright, 2003) and the presence/absence of a floor during carbonization were also considered. Experiments were recently conducted in contexts reconstructed to resemble sites in Sweden (Gustafsson, 2000) and Italy (Guarino & Sciarrillo, 2004), such as Protohistoric houses and fireplaces. These were compared to combustions in laboratory ovens. The depth of burying and the nature of the ground were taken into account in the deformations and disappearance of

seeds. In the Italian cases, few variations in the degree of carbonization were observed between seeds within the same family (*Poaceae*, *Vitaceae*, *Fabaceae*) according to their positions in the ground. On the other hand, remarkable differences were observed in the loss of seeds belonging to different families. These result principally from the sensitivity of different seed types to heating. Cereal grains, for instance, are very sensitive to high temperatures (between 200 and 400°C) and are rapidly carbonized, while grape seeds are completely carbonized starting at 450°C and legume seeds (lentils, chick peas and broad beans) are carbonized starting at 500°C due to the protection provided by their thick tegument.

Over past twenty years, the carbonized residues of cereal stocks have been interpreted based on observations of non-mechanized agricultural procedures (*crop processing sequences*) for cleaning hulled or non-hulled cereals. The proportion of chaff (by-products of cereal processing: awns, barbs, rachis), caryopses and seeds of weed species are the variables taken into account for the identification of the degree and stage of the cleaning of the harvest (Hillman 1981, 1984; Van der Veen, 1992). The modifications of the composition of such assemblages can differ significantly depending on the conditions of carbonization previously described (cf. §1). The quantitative analysis (relative proportions of remains) of such assemblages must take into account the bias created by the differential disappearance of these elements before the stage in the processing sequence can be determined. The parameters were studied at variable temperatures and combustion durations for the components of several hulled or non-hulled cereals (straw, glumes, caryopses) (Boardman & Jones, 1990). One of the conclusions emphasizes that the first components to disappear are precisely those that are the least often represented in carbonized archeobotanical assemblages and those that characterize the first cleaning stages of non-hulled cereals (straws and rachis). These authors focused on the kinetics of carbonization and the destruction of the caryopses of several hulled and non-hulled cereal species in function of the heating duration, temperature and quantity of available oxygen. In order to have a descriptive scale



of the physical state of carbonized caryopses and a tool for the analysis and interpretation of the combustion conditions of archeological seeds, they employed, after modifications, the scales of “Preservation” and “Distortion” of Hubbard (1977 cited by Boardman & Jones, 1990, 4: table 1). Their experiments show that the state of deformation (“Distortion”) is a better descriptor than the degree of preservation (“Preservation”) for determining the conditions in which the seeds of fossil assemblages were burned.

CODE P	PRESERVATION
P 1	Perfect; hairs, etc. preserved
P 2	Epidermis virtually intact, hairs, etc. occasionally preserved
P 3	Epidermis incomplete
P 4	Fragments of epidermis remaining, other features generally unobservable
P 5	Gross morphology only observable
P 6	Vesicular (hollowed), heavily pitted or "clinkered"
CODE D	DISTORTION
D 1	Very little distortion
D 2	Slight distortion
D 3	Clearly distortion
D 4	Gross distortion
D 5	Grain partially destroyed or fused into solid lump

Tab. 1 : Scales used to record the state of preservation and deformation of carbonized seeds (adapted from Boardman & Jones 1990, 4).

The codes are defined following experimental furnace combustion of the non-hulled caryopses of cereals (wheat, barley, rye). The points of destruction of the seed are P5/L or D5; at these stages of experimental combustion, the seed is generally difficult or impossible to determine.

Acorn shelling or the result of carbonization?

The differential preservation of carpological assemblages directly influences interpretations of the function of combustion features and the nature of deposits. However, thermal treatments applied to harvests and food stocks during storage and culinary preparation procedures modify the composition of these assemblages by eliminating certain elements.

Among the farinaceous foods, the acorns of diverse oak species (*Quercus* spp.) also played an important role (Maurizio, 1932; Aurenche, 1997), as is illustrated by discoveries in Protohistoric and historic storage or roasting contexts in both northern (Jorgensen, 1977) and southern (Coularou *et al.*, 2008) Europe. Their

frequent discovery in a shelled or non-shelled state raises the question of the representivity of the preserved and non preserved elements (cotyledons, pericarps and casings) following their combustion. We thus conducted carbonization experiments with sets of whole acorns of evergreen oak and durmast oak (*Quercus ilex* and *pubescens*) (fig. 5A, 5B). The results of this work in progress will allow us to more reliably interpret the nature of acorn deposits discovered in habitats by evaluating the contributions of shelling treatments and destructions related to their carbonization. Our



A



B

fig. 5 : Experimental carbonization of durmast oak (*Quercus pubescens*) acorns, whole and dry at 550°C for 8 minutes (photos L. Bouby).

A – in reducing conditions: all the elements are carbonized, the pericarp is nonetheless roasted in some areas (brownish color); B – in oxidizing conditions: the cotyledons are reduced to ashes, while the casing and the pericarp are carbonized.

objective is to clarify the alimentary role of these fruits for human populations and/or their domesticated animals: the practice of the *glandée*, well illustrated in Medieval western Europe (Mane, 2006, 336), often leads to the conclusion that the consumers of acorns were forcibly swine.

Conclusion

While the carbonization of seeds provides an opportunity to record information that would otherwise have disappeared, it also creates biases in the preservation of carpological assemblages, which all analyses must take into account. These biases concern two principal aspects: size and form of seeds and the qualitative and quantitative composition of carpological assemblages. The examples cited in this paper illustrate the essential role of experimentation in the analysis of these processes. Though it is difficult to precisely mimic archaeological conditions, experimentation is an effective method for testing the effects of different parameters, which must always be defined based on an archeobotanical problematic. It would be of little interest to study preservation by carbonization by itself. It is on the other hand, essential to integrate its effects into methodological procedures that address questions raised by carpological assemblages. The variations in the size and form of seeds can be of great interest in studies of domestication and the relationships between wild and cultivated species. Part of this variability could have a taphonomic origin and be linked to carbonization. While it is necessary to determine if this is the case, this is possible only if the pertinent morphometric criteria have been identified beforehand and if their living variability has been defined through adapted methods and reference bases.

The impact of carbonization on the composition of carpological assemblages can be apprehended only in the context of a broader taphonomic approach integrating the role of human activities, which themselves must be identified. The references in this case are ethnographic or, once again, experimental.

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