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# MEDIEVAL CHARCOALS FROM KOKOTÓW SITE 19 (COMMUNE WIELICZKA) — SOME REMARKS ON THE SAMPLING METHOD AND THE INTERPRETATION OF THE ANTHRACOLOGICAL ASSEMBLAGES

**ABSTRACT**

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During the archaeological excavations conducted at Kokotów site 19 (commune Wieliczka), two habitation structures were discovered in the form of shallow pit-houses and dated to the Medieval period. Charcoal fragments, representing the remains of firewood, were collected from the different layers of these features. This collection of charcoal fragments, illustrates the importance of the sampling method for future data interpretation. They also serve to demonstrate the basis of methodology used for distinguishing these charcoal assemblages leading to more accurate results concerning their palaeoenvironmental interpretation. Moreover, the results are commented on in the context of the anthracological methodology developed within a so-called "Montpellier school". The charcoal assemblages from Kokotów site 19 can be interpreted in terms of past vegetations. During the XII–XIII/XIV centuries, the nearest forest formations were dominated by oak *Quercus* sp., Scots pine *Pinus sylvestris* and hornbeam *Carpinus betulus*, mainly representing oak-hornbeam and mixed pine-oak woods.

Key words: anthracology, charcoal sampling, interpretation of the charcoal assemblages, Medieval period
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# INTRODUCTION

The archaeological excavations at the multicultural site 19 in Kokotów (commune Wieliczka) was conducted during the period of 2005–2007 by A. Matoga from the Archaeological Museum in Krakow as part of the planned construction of motorway A4. The excavations formed part of the works supervised by the Kraków Archaeological Team for the Excavation of the Motorways. It comprised of three scientific institutions: Institute of Archaeology and Ethnology of the Polish Academy of Science, the Institute of Archaeology of the Jagiellonian University, and the Archaeological Museum in Krakow. The archaeological excavations revealed a presence of 310 features, of which the great majority represented graves belonging to the Bronze Age necropolis. On the other hand, only six structures were related to the Medieval period. They were found in the eastern part of the settlement, separated from the Bronze Age necropolis (Matoga 2012).

During the field works, a systematic archaeobotanical sampling was employed, which consisted of gathering soil samples from each archaeological feature and from its different stratigraphic units. Previous works (Moskal-del Hoyo 2012; Moskal-del Hoyo *et al.* 2013) described the results of the anthracological analysis of plant material found in the graves, while this paper presents the analysis of wood remains found within sediments of two medieval features, described as features 72 and 73. They represent some residential remains with hearths inside. They were dated to the XII–XIII/XIV centuries, but it is considered that mainly they were used during the XIII century (Matoga 2012; Pankowski 2012). These features were systematically sampled, providing a great opportunity to illustrate how a sampling method may influence and determine the final results of charcoal analysis, therefore showing the important role it plays in anthracological analysis. This is especially essential if not only palaeoethnographic information is needed, but also a palaeoenvironmental interpretation of the charcoal assemblage is required. However, the latter is only possible when charcoals meet some criteria, which will be presented shortly when providing a background of to the development of the main anthracological concepts.

The archaeological site is located in the northern part of Kokotów, which is situated south-east of Kraków, in a region called the Wieliczka-Gdów Foreland (Gilewska-Starkel 1980 cited after Kadrow 2001, 5). The dominating soils belong to cambisols, while the main types of natural potential vegetation includes mixed opine-oak forest (*Pino-Quercetum*) as well as wet and drier oak-hornbeam forests (*Tilio-Carpinetum stachyetosum* and *Tilio-Carpinetum typicum*, respectively) (Medwecka-Kornaś, Denisiuk, Dziewoński cited after: Kadrow 2001, 11–12, fig. 7 and 8; Matuszkiewicz 2008).

## The basis of the anthracological method developed in "Montpellier school"

Anthracology is a discipline that investigates the remains of wood charcoals from archaeological excavations and natural deposits (Chabal *et al.* 1999, 43). Anthracology provides very valuable information for archaeology, contributing to a better understanding of human practices relating to wood management and botany, giving information about the history of plants and the environmental conditions of the past. Charcoal analysis lays on the boundary between biological and human sciences, and from these two areas two different meanings can be derived: palaeoecological and palaeoethnographic. These assumptions were achieved especially when the number of charcoal analyses significantly increased, starting in the 1960s and 1970s. One of the most important factors was the invention of a reflected light microscope, which enabled the observation of charcoals without the necessity of preparing their thin-sections which resulted in charcoal assemblages being studied in a relatively short time (Badal 1992, 169). In this period, the studies of charcoal samples from different prehistoric and protohistoric sites began to be included in the archaeological synthesis of the individual sites, while the botanical remains formed the basis for a description of the relationship between human groups and their landscape. In this sense, in the field of Anthracology the work of J. L. Vernet (e.g. 1969, 1970, 1972, 1974) should be highlighted. Vernet performed different charcoal studies that gave regional sequences of past vegetation. These studies were conducted at the University of Montpellier and led to an increasing interest for charcoal analysis. In this research centre, later called "Montpellier school" (Asouti and Austin 2005, 2), the basis of methodology in modern anthracology was formulated. Moreover, different problems related to sampling in archaeological sites were solved due to the search of an appropriate method for charcoal collection and its accurate interpretation. Consequently, it was demonstrated that depending on the archaeological context, the charcoals can be interpreted in terms of palaeoenvironment and palaeoethnology (e.g. Vernet 1980; 1985; Vernet and Thièbault 1987; Chabal 1988; 1992; 1997; Thièbault 1988; Badal and Heinz 1991; Badal 1992; Heinz 1991; Figueiral 1992; 1993; Vernet and Figueiral 1993; Théry-Parisot 2001).

The determination of a type of wood used for different purposes is one of the most important questions in any anthracological study. It is widely known that different trees and shrubs have diverse properties (e.g. Johnson 1994; Seneta and Dolatowski 2005) that allow choosing a special wood for a special purpose. Therefore, a similar selection based on wood properties could have been done in the past by human groups. The study of materials used for wooden construction and wood used for the elaboration of diverse tools (e.g. Jaroń 1936; Kostrzewski 1936; Molski 1968; Dzieduszycki 1976; Pétrequin (ed.) 1986; 1989; Chabal 1997, 53; Gale and Cutler 2000; Bosch *et al.* 2006) have demonstrated a strong selection of certain types of species for these reasons. On the other hand, the studies show that two characteristics are present for the use of fuel. First, domestic fires have shown that an indiscriminate use of different types of wood was usually carried out (e.g. Dimbleby 1967, 115; Dzieduszycki 1976; Chabal 1988; 1997; Thièbault 1988; Badal 1992). Also, ethnographic studies have indicated that all kinds of wood are usually gathered as daily fuel (Peńa-Chacorro *et al.* 2000; Ntinou 2002). Second, a special use of fuel, as for industrial purposes, may show a stronger selection of some specific species of flora (e.g. Bielenin 1993; Dzieduszycki 1976; Lityńska-Zając and Wasylikowa 2005, 515–516).

L. Chabal (1988, 195) proposed three models of wood gathering as fuel: (1) the collection of wood based on the knowledge of its properties and on the knowledge of local landscape, (2) the collection without rational basis, especially for ritual purposes, and (3) random wood gathering. The first two models permitted the interpretation of the charcoal assemblage in terms of palaeoethnography since the main criterion for the collection was the species, even though the term *species* did not correspond to present-day botanical classification (Théry-Parisot 2001, 14). The third model proposed by Chabal (1988, 195), in contrast, may serve for gaining palaeoecological meaning of charcoal assemblages since a daily human action such as the gathering of firewood can provide the specific sample of local woody vegetation. In this case, the wood gathering derives from simple necessity, where availability and effort constitute the most important factors (Salisbury and Jane 1940, 310–311; Dimbleby 1967, 115; Chabal 1988, 195, 198; Smart and Hoffman 1988, 169; Ntinou 2002, 117–118; Asouti and Austin 2005, 3–4; Carrión 2005, 31–35). In anthracology, this model is also called “Principle of Least Effort” and was verified by Shackleton and Price (1992). To sum up, some anthracologists believe that fuelwood was gathered on the basis of species selection and according to it, people preferred some species due to its physical properties (combustion’s duration, etc.) and because of that, the charcoal from fires could not offer a real ecological image (Smart and Hoffman 1988, 168; February 1992, 352; Kreuz 1992, 388–390). Some researchers believe that the ecological meaning of the charcoal samples can be achieved only in specific situations (Shackleton and Price 1992, 634–635), whereas the majority of works, especially related to the “Montpellier school”, demonstrate that domestic fires usually provide a great diversity of taxa, which means that the wood gathering could have been made randomly. Moreover, combustion properties attributed to some species vary according to some general characteristics such as humidity, size and the diameter of the wood (Chabal 1992, 224–225; 1997, 44–45; Asouti and Austin 2005, 3–4; Théry-Parisot 2001, 16–19). The type of wood used as fuel is related to the activity for which it was employed. In this sense, the desired property of wood was chosen on different necessities. For example, sometimes a fuel that is consumed quickly was needed (branches, small shrubs, herbs) whereas in other occasions a wood of a long-lasting flame was required (trunks or big branches) (Théry-Parisot 2001; Carrión 2005).

As a result, it is clearly observed that the archaeological context has a major importance in the interpretation of charcoal assemblages. In anthracology, the charcoal directly associated to the archaeological structures of some specific use (posts, graves, funerary fires, hearths, pottery kilns, burnt layers, wooden tools, etc.) provides mostly the palaeoethnographic meaning. This kind of charcoal occurrence is called *concentrated charcoal*. This assemblage usually offers a low diversity of the species and is characterized by short-span or punctual usage and possibly by the special selection of a wood species. On the other hand, the charcoal found spread over the deposits mostly comes from domestic fuel-wood and can provide a palaeoecological meaning. This kind of charcoal occurrence is called *dispersed charcoal*. Its environmental interpretation depends only on a long-span usage of woody species, gathered randomly. It has been observed that fuelwood data obtained from hearths showed a limited amount of taxa due to its punctual usage and the presence of the last burnt species. Meanwhile, the dispersed charcoal as a sum of many hearths' remnants reflects a long period and its results indicate a diversity of taxa that were present in the closest area together with its appropriate percentage (e.g. Chabal 1988, 193–196, 214; 1992, 215–220; 1997, 58–61; Thièbault 1988; Badal and Heinz 1991; Heinz 1991, 301; Badal 1992, 170–187; Heinz and Thièbault 1998, 57; Théry-Parisot 2001, 26–32; Ntinou 2002, 18–23; Asouti and Austin 2005, 3–4; Carrión 2005, 31–35; Lityńska-Zając and Wasylikowa 2005, 275, 279). Some archaeological structures such as pits that lost their primary function and were converted into dumping pits have also the same characteristics as charcoal dispersed in the deposits (Chabal 1988, 214; Bernabeu and Badal 1990; Ntinou 2002, 116; Lityńska-Zając *et al.* 2008; Moskal-del Hoyo 2013).

In Poland, it is interesting to emphasize that the first studies of charcoal samples also demonstrated the importance of their ecological interpretation and some of them are especially significant in the context of the later-formulated concepts of *dispersed/concentrated charcoal*. For example, the results of the analysis of wood charcoal remains from the tumulus of Rosiejów (commune Skalbmierz) were compared by O. Seidl (1936) with the pollen analysis from the Subboreal period. O. Seidl concluded that thanks to the charcoal analysis it is possible to gain an image of local woodland, especially if many remains of charcoal are collected. The author postulated an assumption that a great amount of charcoal documented probably came from a nearby forest and, therefore it may taxonomically represent the composition of that plant community (Seidl 1936, 110–111). J. Zabłocki conducted a study on medieval charcoals of Jeziorko (commune Ryn) with special attention in the methodology of botanical identification and the influence of carbonization on the wood anatomy. In the ecological interpretation of this charcoal assemblage, the author stated that it proceeded from domestic fuel and should represent local shrubs and trees. Consequently, this assemblage may reflect the character of the forest that previously covered the area of the site. Moreover, Zabłocki concluded that thanks to the charcoal analysis of archaeological structures the primary forest can be inferred (Zabłocki 1952, 223). W. Dzieduszycki (1976) analyzed separately the charcoals coming from industrial and domestic fires. The first type of firewood provided less taxa diversity and thus, a special selection of certain species could be assumed. On the other hand, in the assemblages of domestic fires, more taxa were documented. After these observations, Dzieduszycki came to the conclusion that only domestic fuel may serve for the reconstruction of the composition of past vegetation (Dzieduszycki 1976, 48). With the increasing numbers of charcoal analysis, it became evident that the remains associated with firewood collection can be used for the reconstruction of past forest communities (e.g. Kadrow and Lityńska-Zając 1994, 42–52; Lityńska-Zając 2004, 381; Lityńska-Zając and Wasylikowa 2005, 275, 279–281).

In addition, it should be emphasized that the advances of anthracological analyses developed in the "Montpellier school" have demonstrated the major importance of the methodology in order to gain an appropriate palaeoecological meaning of the charcoal assemblage. First of all, a systematic collection of charcoals from different areas of stratigraphic units should be done in order to obtain more representative samples, based on numerous charcoal fragments (Chabal 1988, 208–212; 1992, 216–217; Ntinou 2002, 119). Chabal (1988, 206; 1990; 1992, 226–230; 1997, 45–47) verified the significance of charcoal fragmentation and demonstrated that there is a statistic law, which shows that all species present the same tendency of fragmentation. This law was also confirmed by a study conducted by E. Badal (1992), which showed that the same taxa appear among groups of small (< 5 $mm^3$) and large charcoal fragments. Moreover, some experiments have demonstrated that a fragmentation mostly depends on the heating rate, exposure time or wood temperature (Smart and Hoffman 1988, 172–173) and that is why the statistic law of the same tendency of fragmentation in all species holds (Chabal 1992, 226–230; 1997, 45–51). This problem is also associated with the quantification method. The quantification of the charcoal fragments has always produced controversy because of the fact that the measurement and identification unit is the charcoal fragment, independently of its size. The palaeoecological result is the total sum of them. A solution was needed concerning the relationship between the sum of the fragments and its real representation in terms of the vegetation. The problem was related to the possibility of its interpretation as qualitative and/or quantitative (e.g. Smart and Hoffman 1988, 190–191; Chabal 1990, 1997; Lityńska-Zając 1997; 2004, 380; Lityńska-Zając and Wasylikowa 2005, 276–279). There are a few common methods used to quantify the charcoals. In these methods, fragment numbers and weight measurements, together with ubiquity analysis predominate (Smart and Hoffman 1988; Chabal 1988; 1997; Badal 1992, 171; Asouti and Austin 2005, 3; Figueiral 2005; Lityńska-Zając and Wasylikowa 2005, 276–279). Besides, Chabal (1990, 1997) indicated that the results of the fragments count and weight measurements are highly correlated. Another method was proposed by Kadrow and Lityńska-Zając (1994) and consisted of creating one measurement unit for all the fragments. Nevertheless, the most typical method of quantification consists of counting the charcoal fragments. Besides, the criterion of ubiquity of taxa in different samples and archaeological features is commonly used (ubiquity analysis) and an additional method called "ubiquity correction" of quantification of taxa may also be applied (Moskal-del Hoyo 2010; 2011). This method combines both the relative frequency of taxa and their distribution across the samples. It may also lead to show an overrepresentation of some taxa in a particular sample of the charcoal assemblage.

An adequate number of charcoal fragments analyzed is directly related to the diversity of vegetation developed in the past, and therefore, it is recommended to analyze a minimum of 250 to 400 fragments to obtain a representative charcoal assemblage for one stratigraphic unit/archaeological structure (Badal and Heinz 1991; Heinz 1991, 306; Chabal 1988, 191, 209; Ntinou 2002, 22; Asouti and Austin 2005, 3). A common method to observe the necessary number of charcoal fragments is the use of a taxonomic curve (e.g. Chabal 1988, 208; Badal 1992, 172–173; Ntinou 2002, 22; Carrión 2005). This type of curve may also be helpful if the charcoal assemblage originates from *concentrated* or *dispersed charcoal* (Chabal 1988, 1997; Badal and Heinz 1991; Badal 1992). These curves were proposed for charcoal analysis by F.H. Schweingruber in 1976 (cited in: Chabal 1988, 208) and demonstrate the dynamics of the appearance of a new taxa (Y axis) during the analysis of charcoal fragments (X axis) and presents the different stabilization patterns. Usually, samples that originate from *concentrated charcoal* are characterized by a low diversity of taxa and their stabilization is rather quick. In contrast, the samples coming from dispersed charcoal have more taxonomic diversity and generally the most abundant taxa appear in the first group. The dynamic of the curves increases rapidly at the beginning but further on some new taxa may still be found. These methods can be observed in the examples from Kokotów site 19.

## CHARCOAL ANALYSIS — PRACTICAL ISSUES

It is recommended to obtain charcoal fragments through the flotation or water-sieving of the soil samples. However, in the case of finding large fragments of burned wood, representing *concentrated charcoal*, it is also suggested to gather the sample by hand in order to avoid their further fragmentation and thus their overrepresentation. During the archaeological excavations in Kokotów site 19, soil samples of 10 litres were collected from each stratigraphic unit, belonging to different depths and parts of the archaeological features. The archaeobotanical material was obtained by the flotation of the samples, which took place in the field with the help of the flotation machine (Fig. 1). As a result, two fractions of material were sorted after applying meshes with diameters of 0,2 and 1 mm. Only the remains of wood were found, which were identified using a reflected light microscope with higher magnifications of 100, 200 and 500x. Also, a scanning electron microscope was employed. Each charcoal fragment was broken along its three anatomical sections of wood, namely transverse (Fig. 1, 1), longitudinal tangential (Fig. 1, 2) and longitudinal radial (Fig. 1, 3). Taxonomical identifications were made by comparing the unknown specimens with modern wood collections and by examining the specialized literature (e.g. Schweingruber 1982, 1990). The rank of identification (species, genera, family etc.) depends on the size, anatomical characteristics of the wood, and the state of preservation of the charcoal fragments (Schweingruber 1982; Chabal *et al.* 1999). In addition, the identification of species in Central Europe is mainly determined by the existence of only one species in the local flora (Lityńska-Zając and Wasylikowa 2005, 285). Charcoals were generally well preserved. In general, for the interpretation of charcoal assemblage, plants identified to species, genera and families are only included. In this sense, in the following section when a taxonomic diversity is discussed, it is referred only to the number of identified species, genera and family, counted as the minimum number of species.

A count of charcoal fragments formed the basis of this study, which helped obtain a relative frequency (%) (Table 1). Both features, 72 and 73, probably represented habitation remains, in which two main stratigraphic units were revealed: 1) the first layer was characterized by the evident remnants of burning activities, which were probably related to hearth remains (layer 69/72 and 94/73); 2) the second layer corresponded to a more regular filling of the structure, in which small and dispersed charcoal and daub fragments appeared (layer 70/72 and layer 95/73). Besides, in feature 73 a separate layer 113 was discovered, which consisted of large fragments of burned wood and some charcoal fragments were found inside a pottery pot (Table 1). However, it could be added that in both principal layers, that of the hearth area and off the hearth area, only small fragments of charcoal were found in soil samples. From both areas 25 soil samples were taken during the archaeological excavations. Therefore, these examples may serve for an observation of some relationships between the number of samples, taxonomic diversity and a general abundance of charcoal fragments in the archaeological features. Figure 3 shows that in each sample between 2 to 7 taxa were found, although the majority of them are situated between 5 and 7 taxa. This tendency indicates that if a strategy of sampling methods consists of gathering only one soil sample per stratigraphic unit or archaeological feature, the possibility of finding higher taxonomic diversity is rather low. This possibility may increase if higher numbers of samples is taken. This may be observed in the following examples.

Six samples were taken from layer 69/72, in which 297 charcoal fragments were analyzed and 9 different taxa were documented, while from layer 70/72 only two samples were gathered, which gave 7 taxa (Table 1). Taking into account the taxonomic diversity in both layers, it is more probable that they represent *dispersed charcoal*, even though the first one is associated with the more concentrated hearth remains. Their similarity may be confirmed by using taxonomic curves, which were applied to each layer (Fig. 4). In each layer, the most frequent taxa, such as *Quercus* sp. (oak), *Pinus sylvestris* (Scots pine) and *Carpinus betulus* (hornbeam), appeared in the first 10 charcoal fragments that were analyzed. Five taxa were reached after analyzing 100 charcoal fragments, while in 150 fragments 7 different taxa were found. It is observed that both curves were not stabilized, and it is especially noted for layer 70/72 (Fig. 4), which probably had an insufficient number of charcoals analyzed to obtain any potential for a higher diversity of taxa. Since both layers were rather similar in terms of their qualitative and quantitative analysis, and they belong to the same structure, a combination of both data was possible. As a result, a more stabilized taxonomic curve was achieved from feature 72 (Fig. 5). It means that 150 charcoal fragments

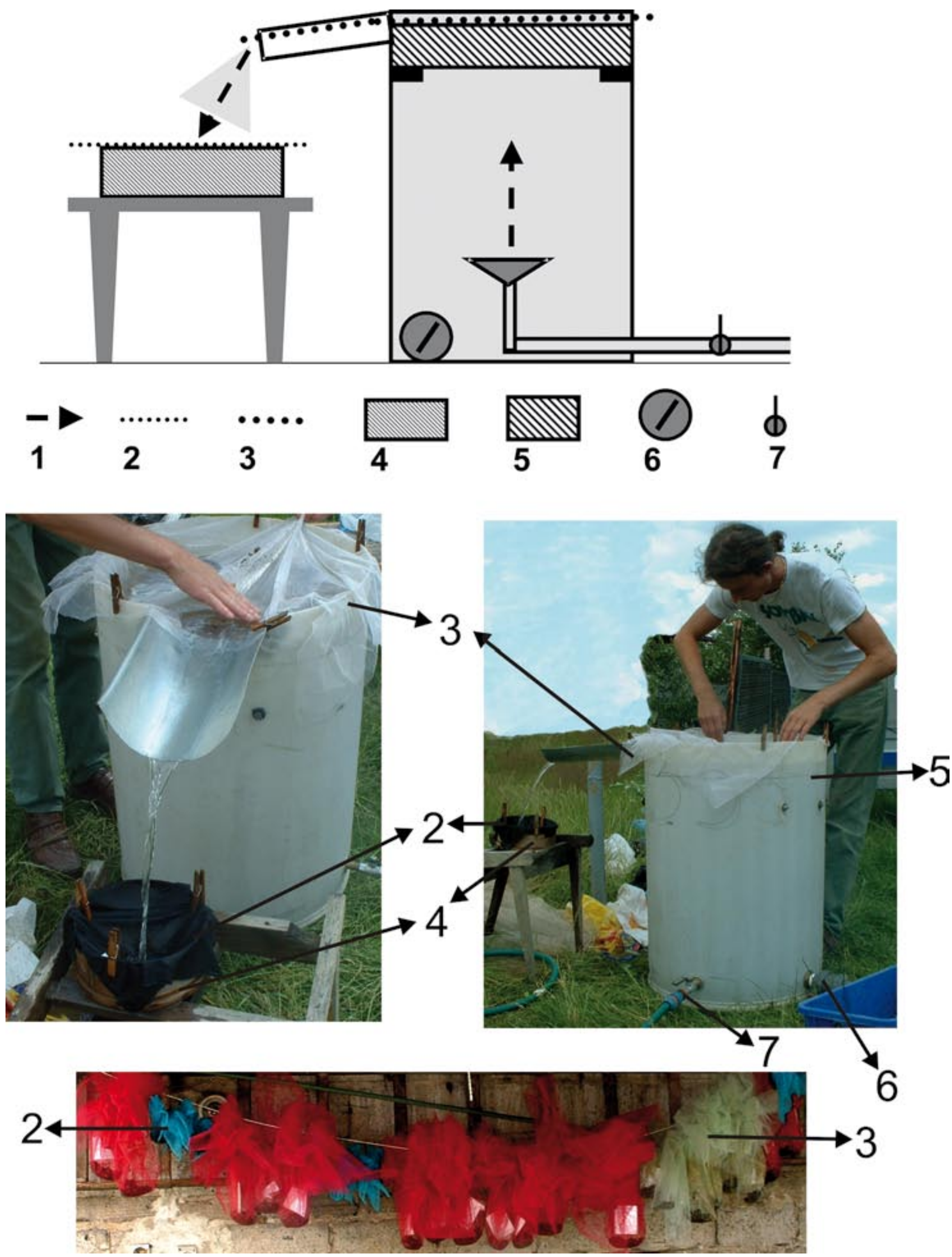


**Fig. 1.** Diagram and photographs of the flotation machine showing its operation during the separation of the charcoals in Kokotów. Explanations: 1 — direction of water flow, 2 — textile mesh of 0.2 mm, 3 — textile mesh of 1 mm, 4 — mesh of 0.5 mm, 5 — mesh of 1 mm, 6 — water valve, 7 — water outflow

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**Table 1.** Absolute (N) and relative (%) frequency of taxa found in two archaeological features from the Kokotów site 19

| **Archaeological feature** | **72** | | | | **73** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stratigraphic unit** | **69** | **70** | **N** | **%** | **113*** | **113** | **pot** | **94** | **95** | **N (94+95)** | **%** |
| *Carpinus betulus* | 37 | 18 | **55** | **12,3** | | 1 | 2 | 115 | 51 | **166** | **24,1** |
| *Cornus sanguinea* | | | | | | | | 6 | | **6** | **0,9** |
| *Corylus avellana* | | | | | | 2 | | 1 | | **1** | **0,1** |
| *Fagus sylvatica* | 1 | | **1** | **0,2** | | | | | | | |
| *Fraxinus excelsior* | | | | | | | | 1 | 1 | **2** | **0,3** |
| *Pinus sylvestris* | 56 | 38 | **94** | **21,0** | 10 | 27 | | 98 | 52 | **150** | **21,7** |
| *Acer* sp. | 1 | 2 | **3** | **0,7** | | | | | | | |
| *Alnus* sp. | 13 | 3 | **16** | **3,6** | | | | 8 | 7 | **15** | **2,2** |
| *Betula* sp. | 3 | 1 | **4** | **0,9** | | | | 6 | 5 | **11** | **1,6** |
| *Quercus* sp. | 156 | 77 | **233** | **52,1** | | 19 | 4 | 166 | 94 | **260** | **37,7** |
| *Salix* sp. | 1 | 2 | **3** | **0,7** | | | | 3 | 3 | **6** | **0,9** |
| *Salix* sp. or *Populus* sp. | 2 | | **2** | **0,4** | | | | 2 | 1 | **3** | **0,4** |
| *Tilia* sp. | | | | | | | | | 1 | **1** | **0,1** |
| *Ulmus* sp. | 5 | | **5** | **1,1** | | | | 1 | 2 | **3** | **0,4** |
| *Viburnum* sp. or *Cornus sanguinea* | | | | | | | | 1 | | **1** | **0,1** |
| Betulaceae | 2 | 1 | **3** | **0,7** | | 1 | 1 | 6 | 1 | **7** | **1,0** |
| Maloideae | | | | | | | | 5 | 1 | **6** | **0,9** |
| Angiospermae | 19 | 8 | **27** | **6,0** | | 8 | 3 | 40 | 10 | **50** | **7,2** |
| Gimnospermae | 1 | | **1** | **0,2** | | | | 1 | 1 | **2** | **0,3** |
| **sum of fragments** | **297** | **150** | **447** | **100** | **10** | **58** | **10** | **460** | **230** | **690** | **100** |
| Number of samples | 6 | 2 | | | 1 | | 1 | 12 | 5 | | |

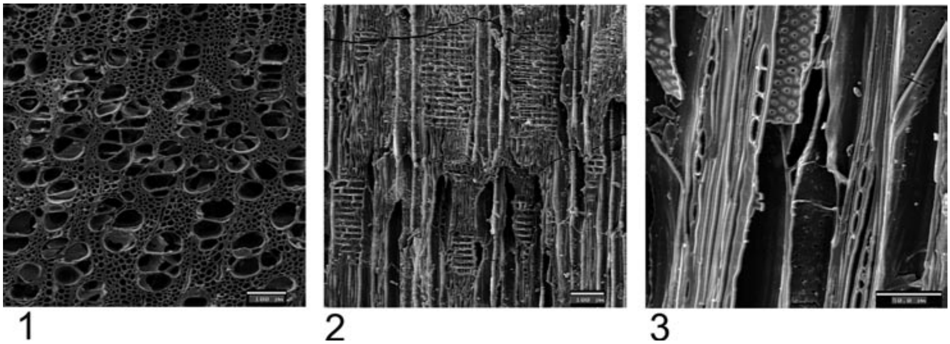


**Fig. 2.** Three anatomical sections of wood: transverse (1), longitudinal tangential (2) and longitudinal radial (3). Micrographs of *Salix* sp. or *Populus* sp. Bar: 100 μm (1, 3) and 50 μm.

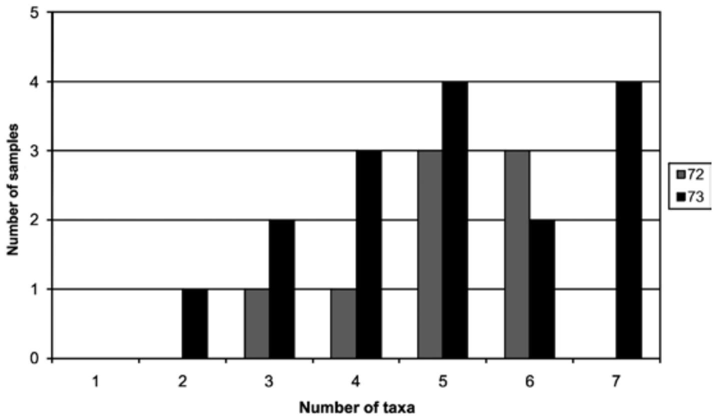


**Fig. 3.** Number of taxa in relation to the number of soil samples

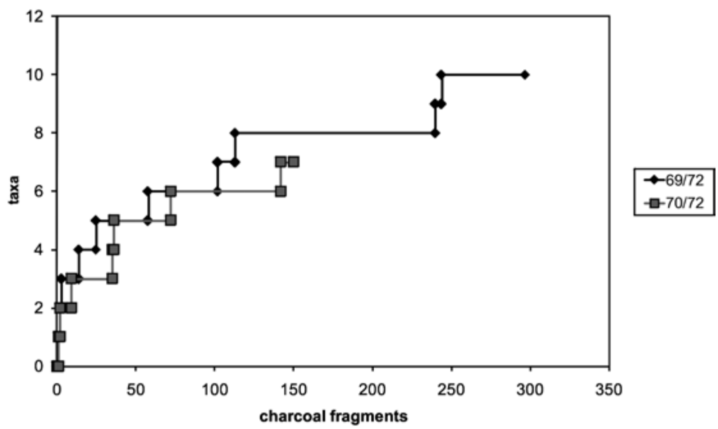


**Fig. 4.** Taxonomic curves applied to the study of the anthracological samples from two layers of feature 72: 69/72 and 70/72

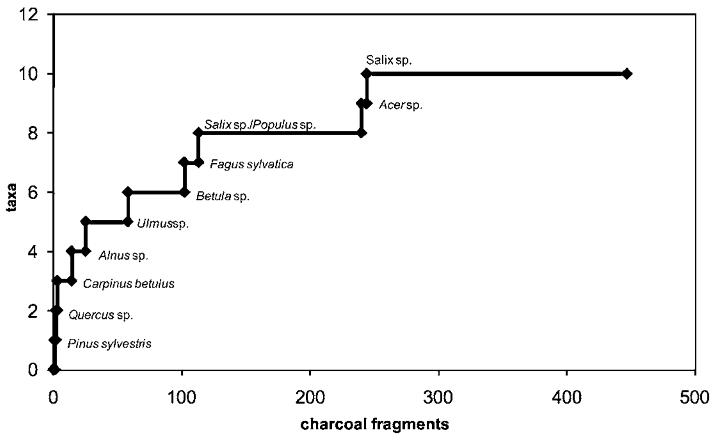


**Fig. 5.** Taxonomic curve applied to the study of all anthracological samples from feature 72

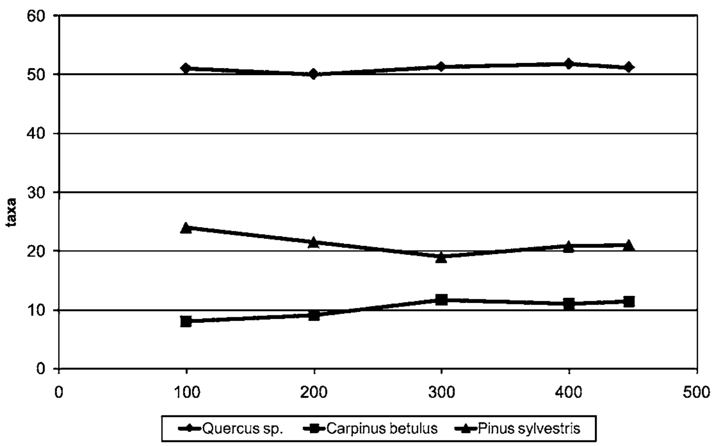


**Fig. 6.** Relative frequency curves applied to the most abundant taxa of the anthracological samples from feature 72

were sufficient enough to find the main and more frequent taxa, while a sum of about 500 analyzed charcoal fragments allowed for the less frequent taxa. The higher the number of charcoal fragments prepared for analysis is also useful in order to acquire a more reliable relative frequency of the main taxa. In each sample, different taxa can reach a different relative frequency, and sometimes they could be overrepresented due to their higher fragmentation in a particular place. Therefore, if more samples are gathered, the problem of overrepresentation of taxa may be reduced and with the analysis of higher numbers of charcoal fragments, their relative frequency can be stabilized. In the example of feature 72, it is observed that the relative frequency of the most abundant taxa, *Quercus* sp., was very

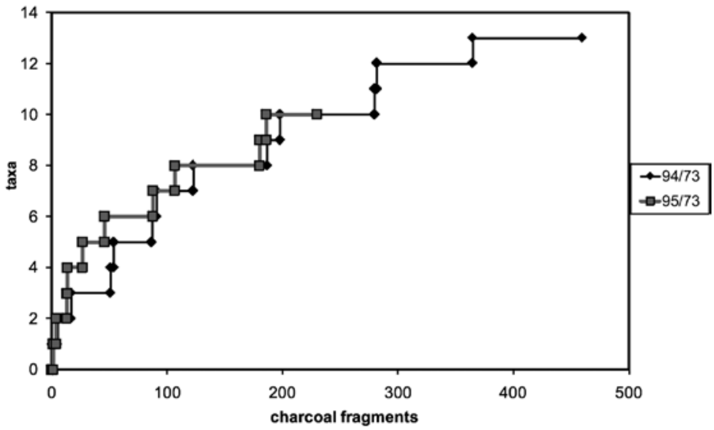


**Fig. 7**. Taxonomic curves applied to the study of the anthracological samples from two layers of feature 73: 94/73 and 95/73

homogenous along the entire analysis since this taxon obtained similar values after analyzing 100, 200, 300, 400 and finally 447 charcoal fragments (Fig. 6). The results of *Pinus sylvestris* and *Carpinus betulus* slightly differed at the beginning and at the end of the analysis and finally were stabilized after analyzing about 400 charcoal fragments (Fig. 6).

The same method was applied to the charcoal assemblage found within feature 73, from which 17 soil samples were collected. The majority of them, 12 samples, came from layer 94. It can be observed that this is the richest layer of charcoal fragments, which also obtained the highest taxonomic diversity. The taxonomic curves applied to the layers 94/73 and 95/73 were very similar since in both a quick increase of new taxa was observed (Fig. 7). The most abundant taxa, such as *Quercus* sp., *Pinus sylvestris* and *Carpinus betulus*, appeared in the first layer in the first 3 fragments analyzed, while in the second one they were found within the first 15 charcoal fragments analyzed. The taxonomic curve from layer 94/73 was stabilized and the last taxon occurred after the analysis of 365 charcoal fragments. On the other hand, the curve from layer 95/73 was still not stabilized since the last taxon was found after the analysis of 186 charcoal fragments (Fig. 7). Since both layers are similar and belong to one archaeological structure, their charcoal assemblages may be combined (Fig. 8). Interestingly, it can be seen that this curve is generally stabilized after the analysis of 500 charcoal fragments, but at the end of the analysis a new taxon still appeared. This is *Tilia* sp. (lime), the final taxon that was found in layer 95/73 and one that was not previously found in layer 94/73. It may also demonstrate a characteristic feature of the charcoal assemblage which originated from the *dispersed charcoal*, in which typically the most abundant taxa appear easily in the first analyzed fragments of charcoals, while the rarest taxa may still be found with the progress of the analysis. In addition, the relative frequency curves applied to the most abundant taxa (Fig. 9) shows that it was

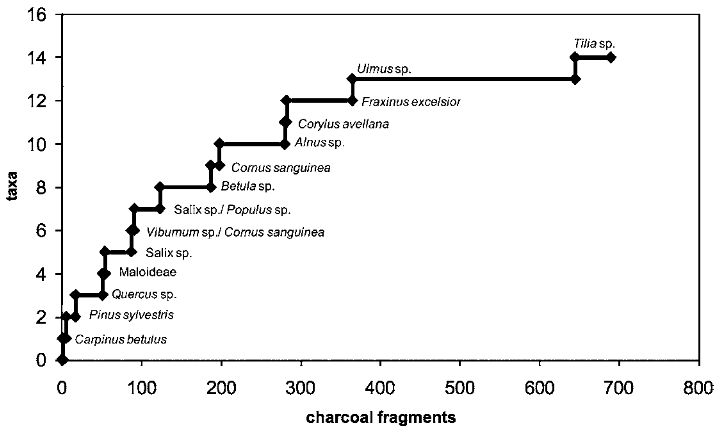


**Fig. 8.** Taxonomic curve applied to the study of all anthracological samples from feature 73

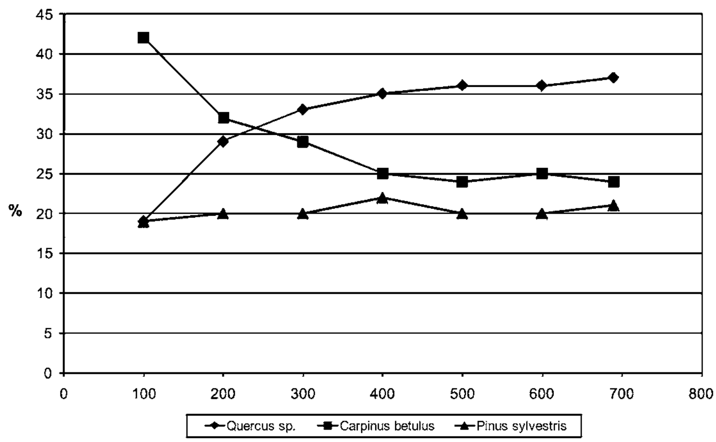


**Fig. 9.** Relative frequency curves applied to the most abundant taxa of the anthracological samples from feature 73

necessary to analyze about 500 charcoal fragments to obtain their stabilization. In the first samples, *Carpinus betulus* was the most abundant taxon reaching between 42% and 32%, while after 400 charcoal fragments this tree obtained about 24%, in comparison to its final frequency in 690 fragments. This difference may be related to the overrepresentation of this taxon in one of the samples studied at the beginning of the analysis. In contrast, *Quercus* sp. was underestimated at the beginning of the analysis, but the incorporation of the other samples in the analysis helped to obtain a more reliable relative frequency of this

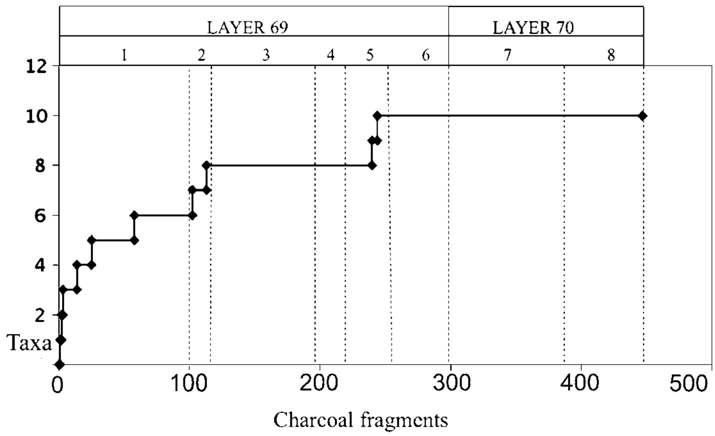


**Fig. 10.** Relative frequency of the main taxa from the charcoal assemblages found in features 72 and 73

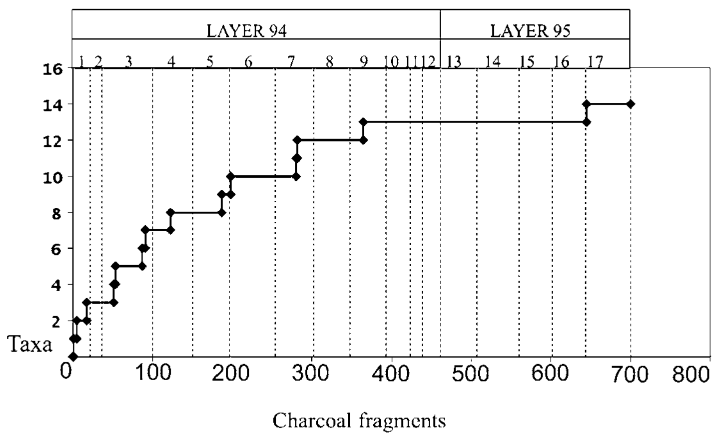


**Fig. 11.** Relative frequency (%) and relative frequency corrected for ubiquity (U%) from the charcoal assemblages found in features 72 and 73

tree. The relative frequency of *Pinus sylvestris* was more or less stable during the entire analysis, situated between 19% and 22%. In summary, in Fig. 10 and Fig. 11 summarized graphs of the anthracological analysis were presented. They demonstrate a general necessity of collecting different samples from a particular archaeological feature since with the increase of the sampled areas, there is a raise of the possibility of finding more taxonomic diversity. This procedure may also help in gaining a more reliable relative frequency of taxa, which is especially important in enabling a reconstruction of the main forest community.

In addition, from feature 73 other samples were also taken. Two of them were collected in stratigraphic unit 113, in which some large fragments of wood were recognized. The first one consisted of fragments that were manually picked-up that belonged to a branch of *Pinus sylvestris*. The second one was gathered as a soil sample and was composed of four different taxa: *Quercus* sp., *Pinus sylvestris*, *Carpinus betulus* and *Corylus avellana* (common hazel; Table 1). These samples, most notably those composed by Scots pine branch, represent the *concentrated charcoal*, which probably can be connected with the remains of the last burning wood. Interestingly, the majority of the charcoal fragments correspond to the main taxa found within the sediment of other layers detected within feature 73. The last sample, which was taken from the fill inside the pottery pot, can also be included in this group since only two taxa were found inside: *Quercus* sp. and *Carpinus betulus*.

The aforementioned examples of the charcoal assemblages differentiated as *dispersed* or *concentrated charcoal* clearly indicate the possibility of their interpretation. The assemblage corresponding to *concentrated charcoal* confirmed a use of some specific kind of wood as fuel and show that wood belonging to *Quercus* sp., *Pinus sylvestris*, *Carpinus betulus* and *Corylus avellana* was collected for this purpose. They probably formed part of the local woodland since firewood was usually gathered in the proximity of the settlements. On the other hand, the study of the assemblages described as *dispersed charcoal* corroborated this observation, but it gave additional information concerning the taxonomic diversity of past forest communities. The indication of predominating trees may also be given with more probability. This may be especially achievable when different charcoal assemblages characterized as *dispersed charcoal* may be studied since the observation of their similarities and discrepancies may lead to formulate a more reliable reconstruction of ancient woodlands. For example, two charcoal assemblages from the abovementioned features 72 and 73 were in general similar qualitatively and quantitatively. In both charcoal assemblages, charcoal fragments of *Quercus* sp., *Pinus sylvestris* and *C. betulus* were the most abundant taxa, although *Quercus* sp. was more abundant in feature 72 (Fig. 12). *Carpinus betulus* was more abundant than *Pinus sylvestris* in feature 73, while in feature 72 it featured less. Other important taxa were *Alnus* sp. and *Betula* sp. They have similar tendencies, but the final values differ slightly. Based on the observation that both charcoal assemblages are rather analogous, their results can be analyzed together. Taking into account the relative frequencies based on a total number of charcoal fragments, *Quercus* sp. obtained 47.2%, *Pinus sylvestris* reached 23.3% and *Carpinus betulus* 21.1% (Fig. 13) In order to get more homogenized results, the relative frequencies of the taxa may be corrected by their ubiquity, which consisted of gaining the mean values of the relative frequencies of each taxon in all of the charcoal assemblages studied (Moskal-del Hoyo 2010, 2011). This method is especially valuable when a higher number of archaeological features are studied. It can be observed that this kind of analysis slightly influenced a lower frequency of *Pinus sylvestris* and a little higher frequency of *Carpinus betulus* (Fig. 13). In any case, both assemblages from Kokotów site 19 can enable the reconstruction of past

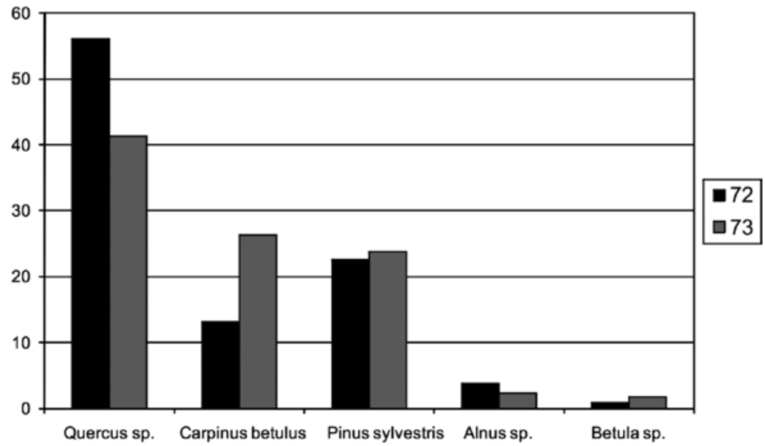


**Fig. 12.** Summarized graph presenting the analysis of charcoal fragments from different samples (shown as vertical dashed lines) found within two layers of feature 72

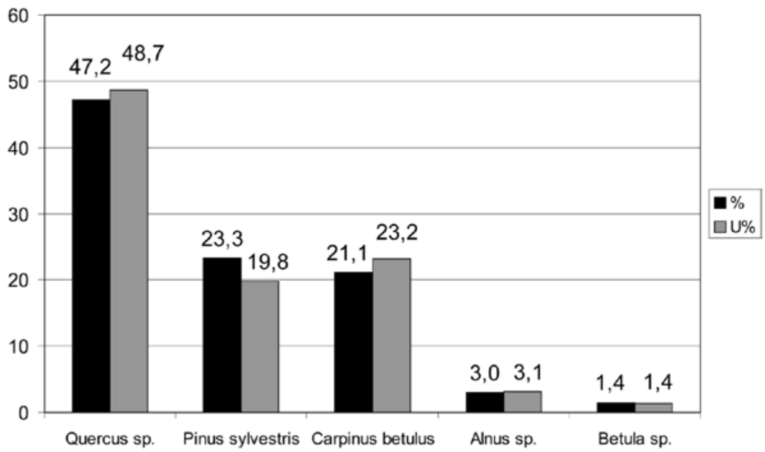


**Fig. 13.** Summarized graph presenting the analysis of charcoal fragments from different samples (shown as vertical dashed lines) found within two layers of feature 73

forest communities due to their taxonomic richness and similarity of the main abundant taxa. Therefore, oak, hornbeam and Scots pine were the most important components of forests developed near medieval settlement, which could represent two major communities: oak-hornbeam and pine-oak forests. The former probably developed on rich soils, while the latter could grow on sandy soils. These results are in accordance with the analysis of the main types of natural vegetation, which included mixed pine-oak forest together with wet and drier forms of oak-hornbeam forests (Kadrow 2001, 11–12, fig. 7 and 8).

The study of present-day oak-hornbeam and pine-oak forests (Medewecka-Kornaś 1972, 403–405, 421–422; Matuszkiewicz 2005, 91–93, 170–186) suggests that *Betula* sp. (birch) could appear in both forest communities, but this tree is more frequently found in pine-oak forests. In contrast, *Corylus avellana* is an important constituent of shrub layer in oak-hornbeam forests. In both forest communities *Fagus sylvatica* (beech), *Populus tremula* (aspen) and different species of *Acer* (maple), *Tilia* and Maloideae occur. The importance of *Alnus* sp. (alder) indicated that some alder woods also grew in the proximity, especially when currently there are some wetland areas close to the settlement. However, this tree can appear as well in more humid forms of oak-hornbeam forest, along with other trees that usually search for soil moisture such as *Ulmus* sp. (elm) and *Fraxinus excelsior* (ash). On the other hand, the last mentioned trees may show the presence of riparian forest with elm, ash, alder and *Cornus sanguinea* (dogwood) — (Matuszkiewicz 2005, 252–254). This kind of riparian forest often occur between oak-hornbeam forests and alder woods, and depending on soil moisture they form mosaic-like patches of forest communities, many of them with transitional characteristics (Matuszkiewicz 2005, 257).

In Kokotów site 19, a relatively high frequency of *Carpinus betulus* should be emphasized since it may shed light on its importance in local woodlands. Usually, this tree tends to be underrepresented in the pollen records as it does not produce large amounts of pollen (Ralska-Jasiewiczowa *et al.* 2004, 71). *Carpinus betulus* represent the most recent group of trees that appeared in Polish flora and its distinct expansion began between 4000 and 3500 BP (Ralska-Jasiewiczowa *et al.* 2004, 72–73). It is a very competitive species, capable of rapid colonization, especially of disturbed forest communities. Different human actions could favour its spread since it is light-demanding, resistant to mechanical damages and damages caused by animal browsing or grazing and regenerates vegetatively. This tree may also have colonized areas of abandoned fields (Ralska-Jasiewiczowa *et al.* 2004, 70–71, 74). Previous studies of the microscopic plant remains in the nearby region, especially in the section located east of Kraków in the area of the Niepołomice Forest, have given rise to the study of the regional history of vegetation (Nalepka 2003). In the pollen diagram from Stanisławice, it was observed that *Carpinus betulus* became more frequent in the Subboreal period and formed parts of mixed mesophilous forests (Nalepka 2003, 106). During the Subatlantic period the pollen values of *Carpinus betulus* decreased, while this period was characterized by the rise of *Pinus sylvestris* (Nalepka 2003, 105–107). This could be interpreted as a consequence of human activity in the area and it is possible that in this period a form of forest similar to the present *Pino-Quercetum* forest could have developed (Nalepka 2003, 107). Unfortunately, there is insufficient data that could be used to connect the XIII-century medieval occupation with a section of the pollen zone corresponding to the Subatlantic period (Nalepka, oral comm.).

## CONCLUSIONS

In summary, it should be stated that the sampling method employed to collect charcoal remains plays a fundamental role in the further interpretation of the data. It has been demonstrated that a single sample usually offers less taxonomic diversity and does not allow for the observance of any tendency in the frequency of taxa in a studied chronological period. Therefore, if palaeoenviromental information is taken into account based on charcoal fragments, a sampling method should consist of gathering various soil samples that would represent different areas and depths of the archaeological assemblages. This procedure may help to obtain samples that would meet requirements of the *dispersed charcoal*. Conversely, a sum of this kind of charcoal assemblages may lead to a formulation of a more reliable reconstruction of past forest communities.

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## References

Asouti E. and Austin P. 2005. Reconstructing Woodland Vegetation and its Exploitation by Past Societies, base on the Analysis and Interpretation of Archaeological Wood Charcoal Macro-Remains. *Environmental Archaeology* 10, 1–18.

Badal E. 1992. L'anthracologie préhistorique: à propos de certains problèmes méthodologiques. *Bulletin de la Société botanique de France* 139. *Actualités Botaniques* 2/3/4, 167–189.

Badal E. and Heinz C. 1991. Méthodes utilices en anthracologie pour l'etude de sites prehistoriques. In: W.H. Walden, J.A. Ensenyat and R.C. Kennard (eds.*), II$^{nd}$ Deya Conference of Prehistory. Recent Developments in Western Mediterranean Prehistory: Archaeological Techniques, Technology and Theory, vol. I: Archaeological Techniques and Technology* (= British Archaeological Reports. International Series 573). Oxford: Archaeopress, 17–47.

Bernabeu J. and Badal E. 1992. A view of the vegetation and economic exploitation of the forest in the Late Neolithic site of Les Jovades and Niuet (Alicante, Spain). *Bulletin de la Société botanique de France* 139. *Actualités Botaniques* 2/3/4, 697–714.

Bielenin K. 1993. *Starożytne górnictwo i hutnictwo żelaza w Górach Świętokrzyskich*. Kielce: Kieleckie Towarzystwo Naukowe.

Bosch A., Chinchilla J. and Tarrus J. 2006. *Els objects de fusta del poblat neolitic de La Draga. Excavacions 1995–2005* (= *Monografies del Casc* 6). Girona: Museu d'Arqueologia de Catalunya. Centre d'Arqueologia Subaquática de Catalunya. Generalitat de Catalunya.

Carrión Marco Y. 2005. *La vegetación mediterránea y atlántica de la Península Ibérica. Nuevas secuencias atracológicas* (= *S.I.P. Serie de Trabajos Varios* 104). Valencia: Diputación Provincial de Valencia.

Chabal L. 1988. Pourquoi et comment prélever les charbons de bois pour la période anticue: les méthodes utilices sur sites de Lattes (Hérault). *Lattara* 1, 187–222.

Chabal L. 1990. L'etude paléoécologique de sites protohistoriques à partir de charbons de bois: la question de l'unité de mesure. Dénombrements de fragments ou pessées? In T. Hackens, A.V. Munaut and Cl. Till (eds.) *Wood and Archaeology. First European Conference, Louvain-la-Neuve, October 2nd-3rd 1987.). Pact* 22: III.5, 189–205.

Chabal L. 1992. La représentativité paléo-écologique des charbons de bois archéologiques issus du bois de feu. *Bulletin de la Société botanique de France* 139. *Actualités Botaniques* 2/3/4, 213–236.

Chabal L. 1997. *Forêts et sociétés en Languedos (Néolithic final, Antiquité tardive). L'athracologie, méthode et paléoécologie* (= *Documents d´Archéologie Française* 63). Paris: Ed. de la Maison des Sciences de l'Homme.

Chabal L., Fabre L, Terral J.-F., Théry-Parisot I. 1999. L'Anthracolgie. In A. Ferdière, Ch. Bourquin-Mignot, J.-E. Brochier, L. Chabal, S. Crozat, L. Fabre, J.-F. Terral and I. Théry-Parisot (eds.), *La Botanique. Collection «Archéologiques»*. Paris: Ed. Errance, 43–104.

Dimbleby G.W. 1967. *Plants and archaeology*. London: Baker.

Dzieduszycki W. 1976. Wykorzystywanie surowca drzewnego we wczesnośredniowiecznej i średniowiecznej Kruszwicy. *Kwartalnik Historii Kultury Materialnej* 24(1), 35–54.

February E. 1992. Archaeological Charcoals as Indicators of Vegetation Change and Human Fuel Choice in the Late Holocene at Elands Bay, Western Cape Province, South Africa. *Journal of Archaeological Science* 19, 347–354.

Figueiral I. 1992. Méthodes en anthracologie: étude des sites du Bronze final et de l'age du Fer du nord-ouest du Portugal. *Bulletin de la Société botanique de France* 139. *Actualités Botaniques* 2/3/4, 191–204.

Figueiral I. 1993. Charcoal analysis and the vegetational evolution of North-West Portugal. *Oxford Journal of Archaeology* 12(2), 209–222.

Figueiral I. 2005 Quantification in charcoal analysis? Yes, but not always. Examples from problematic Portuguese sites. In J. Molera, J. Forjas, P. Roura and T. Pradell (eds.), *Avances en Arqueo-metría* (= Actas de VI Congreso Ibérico de Arqueometría). Girona: Universitat de Girona, 223–228.

Gale R. and Cutler D. 2000. *Plants in Archaeology. Identification manual of vegetative plant materials used in Europe and the southern Mediterranean to c. 1500*. Kew: Westbury and Royal Botanic Gardens.

Heinz C. 1991. Upper Pleistocene and Holocene vegetation in the South of France and Andorra. Adaptation and first ruptures: new charcoal analysis data. *Review of Palaeobotany and Palynology* 69, 299–324.

Heinz C. and Thièbault S. 1998. Characterization and palaeoecological significance of archaeological assemblages during Late and Post-Glacial phases in Southern France. *Quaternary Research* 50, 56–68.

Jaroń B. 1936. Torfowisko z kulturą łużycką w Biskupinie. *Przegląd Archeologiczny* 5(2), 141–147.

Johnson H. 1994. *La Madera*. Barcelona: Blume.

Kadrow S. 2001. Ogólna charakterystyka obszaru badań. In S. Kadrow (ed.), *Przyroda i człowiek. Materiały do studiów* (= *Via Archaeologica. Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce*). Kraków: Krakowski Zespół do Badań Autostrad, 5–21.

Kadrow S. and Lityńska-Zając M. 1994. Analiza materiałów roślinnych ze stanowisk wczesnej epoki brązu w Iwanowicach. *Polish Botanical Studies. Guidebook Series* 11, 31–54.

Kostrzewski J. 1936. Osada bagienna w Biskupinie w pow. Żnińskim. *Przegląd Archeologiczny* 5(2), 121–140.

Kreuz A. 1992. Charcoal from ten early Neolithic settlements in Central Europe and its interpretation in terms of woodland management and wildwood resources. *Bulletin de la Société botanique de France* 139, *Actualités Botaniques* (2/3/4), 383–394.

Lityńska-Zając M. 1997. *Roślinność i gospodarka rolna w okresie rzymskim. Studium Archeobotaniczne*. Kraków: Instytut Archeologii i Etnologii PAN.

Lityńska-Zając M. 2004. Szczątki roślinne z okresu rzymskiego ze stanowisk archeologicznych w polskiej części Karpat. In J. Garncarski (ed.), *Okres lateński i rzymski w Karpatach polskich*. Krosno: Muzeum Podkarpackie w Krośnie, 363–387.

Lityńska-Zając M., Moskal-del Hoyo M., Nowak M. 2008. Plant Remains from Early Neolithic Settlement at Moravany (Eastern Slovakia). *Vegetation History and Archaeobotany* 17. Supplement 1, 81–92.

Lityńska-Zając M. and Wasylikowa K. 2005. *Przewodnik do badań archeobotanicznych*. Vademecum Geobotanicum. Poznań: Sorus.

Matoga A. 2012. Uwagi wstępne. In A. Matoga (ed.), *Kokotów st. 19 (247), gm. Wieliczka. Opracowanie wyników badań*. Kraków (unpublished typescript stored at Archives of Krakowski Zespół do Badań Autostrad).

Matuszkiewicz W. 2005. *Zespoły leśne Polski*. Warszawa: PWN.

Matuszkiewicz J. M. 2008. *Potencjalna roślinność naturalna Polski*. Warszawa: IGiPZ PAN.

Medwecka-Kornaś A. 1972. Zespoły leśne i zaroślowe. In W. Szafer and K. Zarzycki (eds.), *Szata roślinna Polski*. Warszawa: PWN, 383–440.

Molski B. 1968. Gatunki drewna używane w średniowiecznym Szczecinie do wyrobu przedmiotów codziennego użytku. *Archeologia Polski* 12(2), 491–502.

Moskal-del Hoyo M. 2010. Wood charcoal analysis from Neolithic site 1 in Albigowa. Results from excavation conducted in 2002. *Sprawozdania Archeologiczne* 62, 145–159.

Moskal-del Hoyo M. 2011. The ubiquity correction as an alternative method for the quantification of charcoal. In E. Badal, Carrión Y., Grau E., Macías M. and Ntinou M. (eds.), *V^th International Meeting of Charcoal Analysis. The Charcoal as cultural and biological Heritage* (= *Saguntum*), 35–36.

Moskal-del Hoyo M. 2012. The use of wood in funerary pyres: random gathering or special selection of species? Case study of three necropolises from Poland. *Journal of Archaeological Science* 39 (11), 3386–3395.

Moskal-del Hoyo M. 2013. Mid-Holocene forests from Eastern Hungary: new anthracological data. *Review of Palaeobotany and Palynology* 193, 70–81.

Moskal-del Hoyo M., Matoga A., Zysnarska M. 2013. Anthracological analysis from a Bronze Age necropolis at Kokotów (Poland). In F. Damblon (ed.), *Proceedings of the Forth International Meeting of Anthracology: Brussels, 8–13 September 2008*, Royal Belgian Institute of Natural Sciences (= British Archaeological Reports. International Series 2486). Oxford: Archaeopress, 155–164.

Nalepka D. 2003. Prehistoric and historic settlement recorded in a terrestrial pollen profile: Boreal to Subatlantic forest succession in a 60 cm thick sediment in Stanisławice (southern Poland). *Acta Palaeobotanica* 43 (1), 101–112.

Ntinou M. 2002. *La Paleovegetación en el Norte de Grecia desde el Tardiglaciar hasta el Atlántico. Formaciones Vegetales, Recursos y Usos* (= British Archaeological Reports. International Series 1083). Oxford: Archaeopress.

Pankowski B. 2012. Średniowiecze i pierwsze wieki czasów nowożytnych. In A. Matoga (ed.), *Kokotów st. 19 (247), gm. Wieliczka. Opracowanie wyników badań*. Kraków (unpublished typescript stored at Archives of Krakowski Zespół do Badań Autostrad).

Peńa-Chacorro L., Zapata Peńa L., González Urquijo J.E., Ibáńez Estévez J.J. 2000. Agricultura, alimentación y uso del combustible: aplicación de modelos etnográficos en Arqueobotánica. In C. Mata Parreńo and G. Pérez Jordá (eds.), *IBERS. Agricultors, artesans i comerciants. III Reunió sobre Economia en el Món Ibèric. Saguntum, Extra* — 3, 403–420.

Pétrequin P. (ed.) 1986. *Les Sites de Littoraux Néolitiques de Clairvaux-les-Lacs (Jura), I, Problématique générale. L'example de la station III*. Paris: Éditions de la Maison des Sciences de l'homme.

Pétrequin P. (ed.) 1989. *Les Sites de Littoraux Néolitiques de Clairvaux-les-Lacs (Jura), II, Le Néolitique moyen*. Paris: Éditions de la Maison des Sciences de l'homme.

Ralska-Jasiewiczowa M., Miotk-Szpiganowicz G., Zachowicz J., Latałowa M., Nalepka D. 2004. *Carpinus betulus* L. — Hornbeam. In M. Ralska-Jasiewiczowa, M. Latałowa, K. Wasylikowa, K. Tobolski, E. Madeyska, H. E. Wright Jr. and Ch. Turner (eds.), *Late Glacial and Holocene history of vegetation in Poland based on isopollen maps*. Kraków: W. Szafer Institute of Botany, Polish Academy of Science, 69–78.

Salisbury E.J. and Jane F.W. 1940. Charcoals from Maiden Castle and their significance in relation to the vegetation and climatic conditions in prehistoric times. *Journal of Ecology* 28, 310–325.

Schweingruber F.H. 1982. *Mikroskopische Holzanatomie*. F. Flück-Wirth, Internationale Buchhandlung für Botanik und Naturwissenschaften, Teufen.

Schweingruber F.H. 1990. *Anatomie Europäischer Hölzer*. Bern-Stuttgart: Paul Haupt Berne und Stuttgart Publishers.

Seidl O. 1936. Przedhistoryczne węgle i owocki *Lithospermum* z kopca wschodniego w Rosiejowie w pow. pińczowskim. *Wiadomości Archeologiczne* 14, 106–115.

Seneta W. and Dolatowski J. 2004. *Dendrologia*. Warszawa: PWN.

Shackleton C.M. and Prins F. 1992. Charcoal Analysis and the "Principle of Least Effort" — Conceptual Model. *Journal of Archaeological Science* 19, 631–637.

Smart T.L. and Hoffman E.S. 1988. Environmental Interpretation of Archaeological Charcoal. In Ch. A. Hastorf and V. S. Popper (eds.), *Current Palaeoethnobotany. Analytical Methods and Cultural Interpretations of Acrhaeological Plant Remains*. Chicago: Chicago University Press, 167–205.

Thiébault S. 1988. *L'Homme et le milieu végétal. Analyses anthracologiques de six gisements des Préalpes au Tardi-et au Postlaciaire*. Documents d'Archéologie Française. Editions de la Maison des Sciences de L'Homme de Paris, Paris.

Théry-Parisot I. 2001. *Économie du combustible au Paléolithique. Anthracologie, Expérimentation, Taphonomie*. Dossier de Documentation Archéologique 20. C.N.R.S., Paris.

Vernet J.-L. 1969. Une cabane acheuléenne dans la Grotte du Lazaret (Nice). *Mémoire de la Société Prehistorique Française* 7, 127–128.

Vernet J.-L. 1970. Analyse de charbons de bois de niveaux Tardiglaciaire et Post-Glaciaires de l'Arma de Nasino (Savone, Italie). *Naturalia monspeliensia,* série Botanique 21, 243–246.

Vernet J.-L. 1972. Nouvelle contribution à l'histoire de la végétation holocène des Grands Causses d'après les charbons de bois. *Bulletin de la Société Botanique Française* 119, 169–184.

Vernet J.-L. 1974. Précisions sur l'évolution de la végétation depuis la Tardiglaciaire dans la regions méditerranéenne, d'après les charbons de bois de l'Arma de Nasino (Savone-Italie). *Bulletin de L'Association Française pour l'Etude du Quaternaire* 39, 65–72.

Vernet J.-L. 1980. La végétation de Bassin de l'Aude, entre Pyrénées et Massif Central, au Tardiglaciaire et au Postglaciaire d'après analyse anthracologique. *Review of Palaeobotany and Palynology* 30, 33–55.

Vernet J.-L. 1985. Écologie des Causses au Quaternaire. *Bulletin de la Société Botanique Française* 19 (3–4), 265–285.

Vernet J.-L. and Figueiral I. 1993. The highlands of Abodoreira (North-West Portugal): ecological conditions from Middle/Late Neolithic to Early Bronze Age. Evidence from charcoal analysis. *Oxford Journal of Archaeology* 12 (1), 19–28.

Vernet J.-L. and Thiébault S. 1987. An approach to northwestern Mediterránean recent prehistoric vegetation and ecologic implications. *Journal of Biogeography* 14, 117–127.

Zabłocki J. 1952. Szczątki roślinne ze stanowiska wczesnośredniowiecznego w Jeziorku, powiat Giżycko wydobyte w r. 1950. *Materiały wczesnośredniowieczne* 2, 211–225.