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# Radiocarbon Dating in Archaeological Sites Chronology

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## 1. Introduction

Charcoal and bones are materials commonly used for the radiocarbon dating in geological and archaeological research. The difficulties with <sup>14</sup>C dating of charcoal and wood may be associated with the origin of analysed fragments, the conditions of the sediments, such as pH or humidity. As far as bones are concerned, the difficulties with radiocarbon dating may be connected with their state of preservation, collagen presence and the possible contamination by carbon from other sources.

In some cases, despite the standard method of chemical pretreatment, it may be necessary to customise the applied treatment to the investigated material. The results of radiocarbon dating of bones and wood were compared with the relative chronology established by archaeologists, based usually on the typology of artefacts or pottery.

The presented results of analyses refer to the territory of Wielkopolska (Great Poland), including among others, prehistoric and early medieval settlement sites in Suchy Las, Łęki Wielkie, Szczodrzykowo, Trzcielina, Snowidowo, Żerniki and Zielęcina (fig. 1). Samples of bones and pieces of wood selected for dating come from different periods of time and various cultures distinguished in archaeology, from the Funnel Beaker culture and the Lusatian culture to the developed phases of the Early Middle Ages (fig. 2). The history of the settlement in Wielkopolska, a historical Polish district comprising the basin of the central Warta River, is quite complex (Kobusiewicz, 2008). The origins of occupation in the area, recognised by archaeologists, date back to the late Paleolithic, about 12-10 millennia BC. The Mesolithic and Neolithic hunter-gatherer communities lived here in the period between 9 and 3 millennium BC. The first agricultural societies appeared in the Neolithic, namely 6-3 millennium BC (the Linear Pottery culture, the Funnel Beaker culture, the Globular Amphora culture, the Corded Ware culture). They were followed by communities of the early Bronze Age (the Iwono culture, the Únětice culture and the Trzciniec culture), the developed Bronze Age societies (the Lusatian culture), early Iron Age cultures (the Pomeranian, the Jastorf and the Przeworsk), the cultures of the period of the Roman influences (the Przeworsk and the Wielbark), and finally the early Medieval settlement, when the Polish statehood began to emerge.

Some of these archaeological cultures, such as Lusatian or Przeworsk, are characteristic only for the selected area of Central Europe, among others the Czech Republic, Poland and Germany.

Poznań, which currently is the capital of Wielkopolska, obtained city rights in 1253, but it fulfilled the role of a centre, the most important stronghold already since the times of Duke Mieszko I of the Piasts dynasty, in the end of the 10th century.

For the majority of the presented sites from the Wielkopolska Province,  $^{14}\text{C}$  dates have been collected for the first time (with the exception of site 4 in Łęki Wielkie) and they have been intended to help determine the chronology, possible phases of development or point to the beginnings of given strongholds.

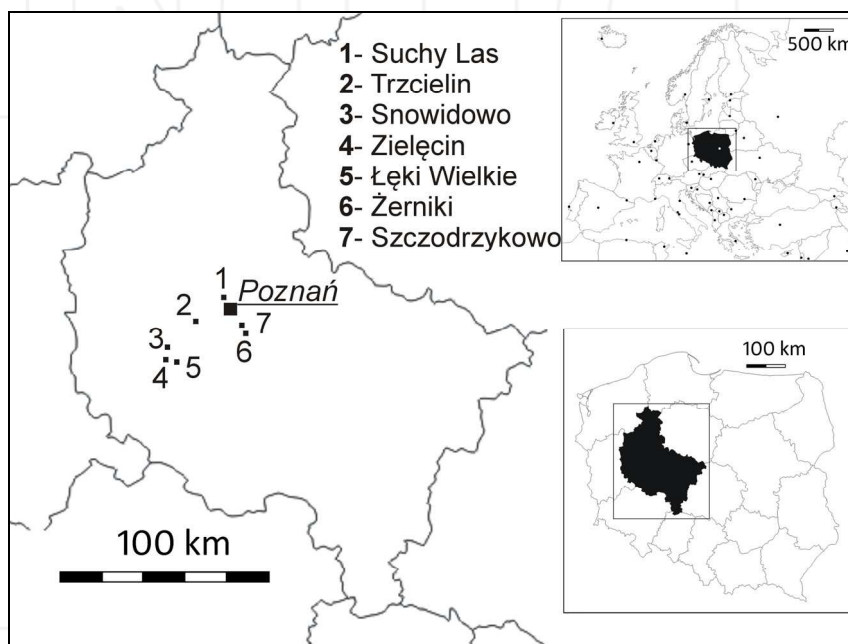


Fig. 1. The studied area against the background of Europe, Poland and the Wielkopolska Province.

## 2. Archaeological background

The dated samples come from a few archaeological sites from the Wielkopolska Province, situated in the vicinity of Poznań. They are located in the area of Trzcielín, Suchy Las, Żerniki, Zielęcín, Snowidowo, Łęki Wielkie and Szczodrzykowo (fig.2). These sites are chronologically diversified and some of them yielded a number of chronologically and culturally varied developmental phases. However, the presence of the Early or Late Middle Ages on the majority of them, is a common trait. Remains of the Przeworsk culture are less frequent here. Some of the cultures present in the analysed area are characteristic only for Central Europe.

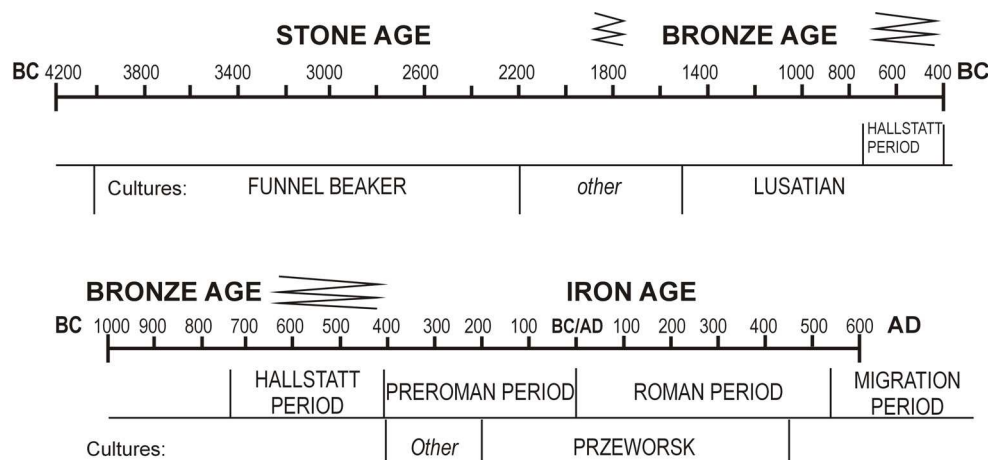


Fig. 2. Chronology and archaeological cultures of the Wielkopolska region discussed in the paper (*other cultures* – cultures occurring in the analysed region, from which there were not any samples available).

## 2.1 Suchy Las

Archaeological excavations conducted in 2007 at site 6 in Suchy Las near Poznań produced archaeological material from five chronological horizons (basing on relative chronology) related to:

- the communities of the Funnel Beaker culture from the Neolithic (from about 3200 until about 2500 BC),
- the communities of the Pomeranian culture from the Early Iron Age (from about 400 BC till the turn of the eras),
- the Early Middle Ages – from the 13<sup>th</sup> – 14<sup>th</sup> century,
- the Late Middle Ages – from the end of the 14<sup>th</sup> – the beginning of the 16<sup>th</sup> century
- the modern period – from the 17<sup>th</sup> -19<sup>th</sup> century.

The early medieval village of *Zuchilecz* (Suchy Las) was first mentioned in written sources in 1170 (Długosz, 1874). It was suggested that the village had been granted by Mieszko the Old and given to the order of St. John of Jerusalem, who had run a hospital of St. John of Jerusalem in Poznań in the 2<sup>nd</sup> half of the 12<sup>th</sup> century.

## 2.2 Trzcielín

Archaeological Site 63 in Trzcielín is located in the district of Poznań. The site yielded an extensive early medieval settlement, recognised mainly on the basis of artefacts. Apart from the Early Middle Ages, that can be probably divided into two phases, and the modern period, (the 17<sup>th</sup> -beginning of the 20<sup>th</sup> century), the 2009 excavations produced also a prehistoric horizon, probably dating to the Neolithic (second half of the 2<sup>nd</sup> millennium BC). For dating purposes, a sample from feature 64 was collected. Archaeologists date this feature back to the Middle Ages.

For these kind of features the obtained date is significant in terms of the possibility of chronological verification of the development of feudal relations in Wielkopolska. In this case, it was a subordinated production settlement site, where significant quantities of turf ore were smelted, also for its inhabitants. It was also an important settlement site in view of the needs of a nearby central stronghold of Poznań, as a duke's superior centre.

### 2.3 Snowidowo

Excavations at site number 9 in Snowidowo, carried out in 2009, produced four settlement complexes:

- a trace of prehistoric occupation (probably from the Neolithic),
- a settlement site of the Przeworsk culture from the late pre-Roman period,
- a trace of occupation from the Early Middle Ages (from phase F),
- a settlement point from the modern period.

There is also the hypothesis of possible distinguishing between different development phases of the Przeworsk culture, a pre-Roman (from 2nd cent. BC till BC/AD) and a Late Roman settlement.

### 2.4 Zielęcín

A previously unknown archaeological site 15 in Zielęcín was discovered in the course of excavations conducted in 2009. It yielded modern features and features dating back to the early phases of the Early Middle Ages. Based on the production techniques of pottery, part of the settlement site from which the samples were collected was dated to the 6<sup>th</sup> and 7<sup>th</sup> century A.D. Therefore it is an assemblage related exclusively to A-A/B type of the early medieval pottery in the Pomerania region according to the classification of Łosiński & Rogosz (1983, 1986). Almost all pottery is hand-formed (without the usage of a potter's wheels) with no decoration. In view of its early chronology, within the turn of Antiquity and the Early Middle Ages, the scientific value of the discovered site is enormous. It is also related to the question of the appearance of the earliest assemblages with the Slavic pottery in the area of Wielkopolska.

### 2.5 Łęki Wielkie

Site number 4 in Łęki Wielkie was discovered in 1933 and verified in 1987. The most recent excavations were conducted in 2009. The following cultural units have been registered:

- a settlement site of the Przeworsk culture,
- a settlement site accompanying a stronghold from the Early Middle Ages (from phase C),
- a trace of occupation from the Late Middle Ages (15<sup>th</sup> -16<sup>th</sup> century),
- a trace of occupation from the modern era (17<sup>th</sup> - beginning of the 20<sup>th</sup> century).

The sample selected for dating purposes came from a settlement accompanying a stronghold from the end of the 9<sup>th</sup> century till about the 1<sup>st</sup> half of the 10<sup>th</sup> century AD (Early Middle Ages, phase C), basing on relative chronology.

Radiocarbon dating was supposed to determine the chronological relationship between the settlement site and the nearby early medieval stronghold, representing a moment of the

transition between the tribal period and the emerging early Piast state, interesting for the history of Wielkopolska. An extensive settlement site near the stronghold, several dozen hectares in size, has been tentatively dated (only on the basis of the traits of the pottery) to the period from the end of the 9<sup>th</sup> century to about 1<sup>st</sup> half of the 10<sup>th</sup> century (Kara & Krąpiec, 2000).

According to the sources obtained from survey excavations in the 1980s, the nearby stronghold was analogously dated. The <sup>14</sup>C date was intended to confirm unambiguously the dating determined exclusively on the basis of the typology of archaeological sources.

## 2.6 Żerniki

Archaeological site in Żerniki was discovered and excavated in 1986. Excavations, continued in 2009 due to a local industrial investment, produced four chronological horizons (fig. 2):

- a trace of occupation from the Neolithic (2<sup>nd</sup> half of the 2 millennium BC),
- a settlement site of the Przeworsk culture (4<sup>th</sup> century AD),
- a settlement point from the Early Middle Ages (12<sup>th</sup> -13<sup>th</sup> century AD),
- and a settlement point from the modern period (17<sup>th</sup> - beginning of the 20<sup>th</sup> century).

The most valuable materials from the site are related to the Przeworsk culture. On the site the greatest number of features were registered and the rescue excavations were aimed at recognising as much of the spatial range of the settlement site as possible. Both features chosen for dating purposes come from horizons related to the settlement of the Przeworsk culture (3<sup>rd</sup> -4<sup>th</sup> century AD). Although a great number of features dating back to this period were excavated, there were not enough sources for the precise determination of the time of its existence. The possibility of determining the chronological variability within the same settlement site was also a significant aspect of the conducted studies.

Apart from one Roman coin (follis) from the times of emperor Constantine I and two fibulae (type A.158 and A.162 (Almgren, 1923), excavated outside features, it was not possible to determine the chronology of the majority of open elements of this settlement site (such as lime kilns, postholes or heaps of fired lime).

## 2.7 Szczodrzykowo

The analysed site is located in the commune of Kórnik, south-east of Poznań. The finds in the area of site number 4 in Szczodrzykowo point to the existence of a multicultural settlement site here, namely (fig. 2):

- a Stone Age trace of occupation,
- a settlement site of the Lusatian culture,
- a settlement site of the Przeworsk culture,
- a settlement site from the early Middle Ages,
- a trace of occupation from the modern era.

## 3. Sample description

The material from the area of Wielkopolska collected for dating purposes includes mostly samples of wood and fragments of human and animal bones excavated at sites, in archaeological layers of varied chronology (Fig.2, 3 and 4).

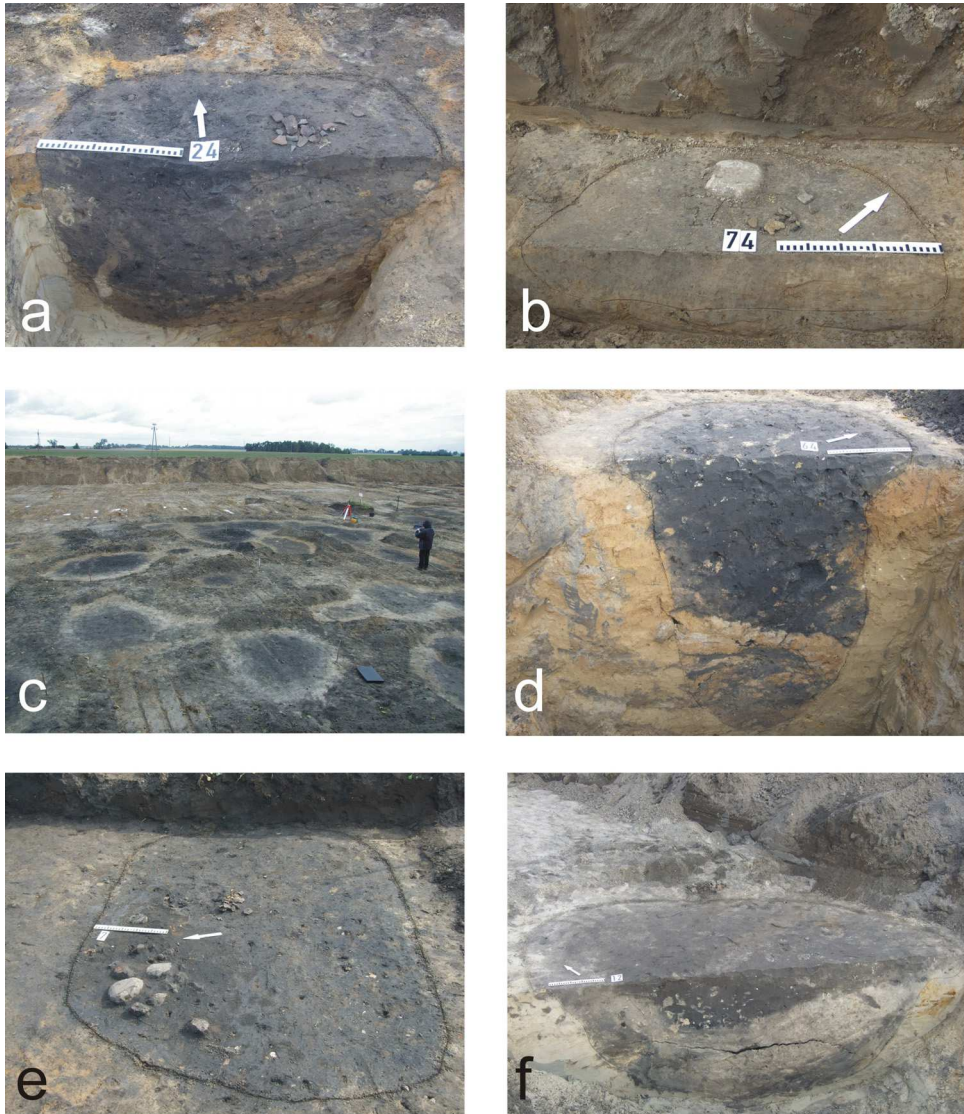


Fig. 3. Chosen archaeological sites: a) Suchy Las, feature 24 – storage pit that contained one of the samples of bones for dating; b) Snowidowo, feature 74 that contained the dated bone; c) Trzcielín – general view of excavations; d) Trzcielín - feature 64, from which a sample of an animal bone was collected for dating; e) Zielęcín, feature 7 – half dugout from which a sample for  $^{14}\text{C}$  measurement was collected; f) Łęki Wielkie, feature 12 – a dwelling structure – half dugout, from which a bone was collected for dating.

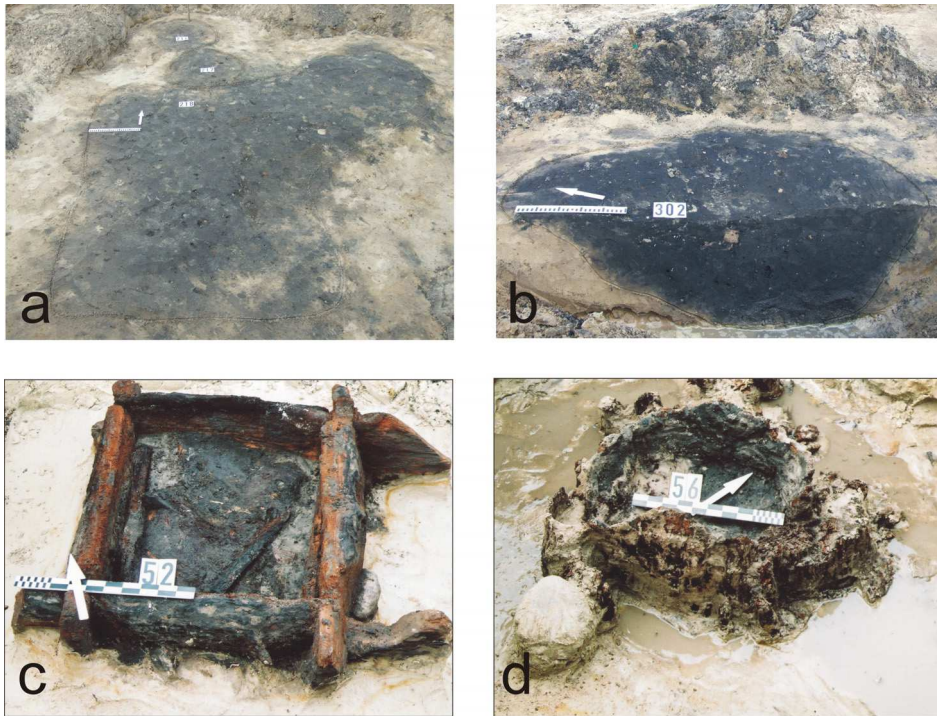


Fig. 4. Chosen archaeological sites; a) Żerniki - feature 218 - a dwelling structure from which the first bone sample was collected; b) Żerniki - feature 302 - a storage pit, from which the second bone sample was collected c) Szczodrzykowo, wells of varied age with wooden lining, from which wood samples were collected for dating - feature 52 (late medieval); d) Szczodrzykowo - feature 56 (the Lusatian culture).

### 3.1 Suchy Las

Two samples from the chronological horizon related to the Middle Ages were selected for radiocarbon dating:

- a sample dated by archaeologists on the basis of relative chronology to the period from the end of the 10<sup>th</sup> century till the 1<sup>st</sup> half of the 11<sup>th</sup> century, (phase D2);
- the period from the 2<sup>nd</sup> half of 11<sup>th</sup> century till 1<sup>st</sup> half of the 12<sup>th</sup> century (phase E2).

Both samples are animal bones from features 24 and 26. Feature 24 is a storage pit, whereas feature 26 is a dwelling structure, a half dugout (fig.3a).

### 3.2 Trzcielín

A sample selected for <sup>14</sup>C dating was procured from a part of the site estimated by archaeologists to the Early Middle Ages (late 10<sup>th</sup> century to the turn of the 11<sup>th</sup> and 12<sup>th</sup> century). It was an animal bone chosen out of more than 1,200 bones from feature 64. The function of this feature has not been fully recognised. In the first phase it was probably a

bloomery, whereas once the activities relating to the smelting (or processing) of the iron raw material were abandoned, it began to fulfil the role of a rubbish pit.

### 3.3 Snowidowo

In terms of the chronology, a sample chosen for dating came from part of the site related to the Przeworsk culture, preliminarily estimated by archaeologists to the pre-Roman Period. The assemblage of finds from this chronological period numbered, among others, 84 features and only 157 potsherds. A chosen sample of an animal bone was collected from feature 74.

### 3.4 Zielęcín

Samples selected for  $^{14}\text{C}$  measurements are animal bones from features 6 and 7. In both cases they were excavated within the dwelling structures (half dugouts), in the area of an early medieval settlement site. A phase of this part of the settlement was preliminarily dated to the period of the Middle Ages (phase A-B) on the basis of the production techniques of the pottery. In terms of archaeological sources it is a period between the end of the 6th and 7th century AD.

### 3.5 Łęki Wielkie

The material chosen for dating from this site is an animal bone from a dwelling structure – a half dugout. The site is a settlement accompanying the stronghold (phase C of the Middle Ages) estimated by archaeologist on the basis of relative chronology to the period from the end of the 9th century till about the 1st half of the 10th century AD.

### 3.6 Żerniki

Both features selected for dating are dated to the horizons related to a settlement site of the Przeworsk culture (3rd – 4th century AD). For  $^{14}\text{C}$  analyses two animal bone samples were chosen: from feature 218 – the only dwelling structure, and feature 302 – a storage pit that contained a glazed glass bead imported from the territory of the Roman provinces.

### 3.7 Szczodrzykowo

The material selected for radiocarbon dating comes from two features. The first one (fig. 4d), feature 56, represents a settlement site of the Lusatian culture (from the Hallstatt period, namely from the 7th -5th century BC). It is a fragment of wood from a well with a wooden lining made of a burnt tree trunk. The other sample is a wooden fragment from feature 52, qualified to a settlement site from the Late Middle Ages (14th century, fig. 4c)). The sample has also been taken from a wood-lined well, however in this case the well was erected by stacking logs one on top of another and overlapping them at the corners. The age ranges for both features were established on the basis of archaeological research and absolute dating verification is needed.

## 4. Geological background

The studied archaeological sites are located in the central-western part of Poland (Wielkopolska region). This area is characterized by postglacial relief and its morphological

features were shaped by glacial and fluvial processes during the Weischelian glaciation in late Pleistocene and Holocene. Consequently, late Quaternary deposits in the Wielkopolska, specifically in the vicinity of Poznań, are dominated by glacial tills, fluvioglacial sands and gravels as well as alluvia of the Warta river. The former are exposed in the end moraines of the Poznań phase and the latter two are encountered in the Warta river marginal valley (Stankowski, 1996).

$^{14}\text{C}$  dating was performed on the fragments of bones, excavated from mineral substratum, mentioned above. In the Suchy Las and Trzcielín sites the material for age determination was found within loamy sands, however, in the latter the sand co-occurred with glacial till. In the Łęki Wielkie, Żerniki and Snowidowo, the parent material consisted of fine-grained sand. In Snowidowo the sand laterally changed to glacial till. In Zielęcín the bone fragments were extracted from sandy till and in Szczodrzykowo – from sandy till surrounded by fine sands.

The sampled material was evidently influenced by physical and chemical processes operating in agricultural landscape. The area where study sites are located, has been extensively used for agricultural purposes and fertilization of the soils. Migration of soil solutions led to secondary changes within the fossil bones, and consequently, to inaccurate radiocarbon age.

## 5. Methods

Wood and bone samples, chosen from each site, were radiocarbon dated using the technique of AMS in The Poznań Radiocarbon Laboratory. The laboratory is equipped with a accelerator mass spectrometer type 1,5 SDH-Pelletron, Model „Compact Carbon AMS”.

Fragments of charcoal and wood are most frequently used materials for radiocarbon dating. However, the results of dating wood and charcoal do not always reflect the time of cutting down a tree. A tree grows successively, building on subsequent rings each year. Depending on whether the analysed fragment comes from a central part of a trunk or a young twig, or whether it is a group of mixed charcoal fragments collected from an archaeological layer (McFadgen, 1982; Ashmore, 1999), there might occur significant discrepancies between the radiocarbon age and the age of the relevant archaeological level.

In the context of archaeological sites, the likely time lapse between the moment of cutting down a tree and using it for erecting structures, or the possibility of re-using building materials seems to have much less influence.

The preparation protocol for individual samples is important because of different preservation stage, sample size and possible samples loss during treatment (Nawrocka et al., 2007, 2009; Rebollo et al., 2008; Szczepaniak et al., 2008). The first stage of wood and charcoal purification was removal of macroscopically visible plant roots. Then the samples have been subjected to the “acid-base-acid” (ABA) preparation step by treatment with 1M HCl solution. The aim of this step was to dissolve carbonates and other soluble minerals. The second stage was submerging the samples in the base solution (0,025 M NaOH and 0,5 M NaOH) to remove humic compounds. The last ABA step was the repeated acid treatment (0,25 M HCl). Each time, the samples were bathed in deionised water to restore the neutral pH.

Subsequently the wood material was subjected to a bleach pretreatment with sodium chlorite ( $\text{NaClO}_2$ ) to remove lignins, resins, waxes. In case of very small samples or poorly preserved fragments the temperature and the time of each step was individually match. In the next stages of samples preparation to dating the combustion in vacuum to obtain carbon dioxide from organic material and reduction were used. Finally, graphite with iron was pressed to form a cathode ready for AMS measurement.

The age of bones excavated at archaeological sites is usually closely related with the period of its functioning. The content of material relevant for dating, e.g. collagen in case of bones, depends on their age, state of preservation or depositional environments. Remarks on the state of collagen preservation are given in Table 1. One of the major mistakes which occurs while dating bones is the contamination by humus acids and carbonates of a different origin. At the same time the pretreatment, aimed at eliminating contamination, may cause partial loss of material, as the collagen is susceptible to the effect of concentrated solutions. Almost all samples contained enough collagen for dating.

If the amount of collagen extracted from the sample is lower than 1% of the starting weight of the bone material used, the sample is usually rejected prior to dating.

During the process of transformation of the sample to  $\text{CO}_2$  in the laboratory, the reliability of dating the sample is controlled by various parameters. The carbon content of the product should be between 30 and 50% of the weight of the collagen. Values beyond this range are indicative of contamination or degradation. The C:N atomic ratio should be between 2.9 and 3.5 (van Klinken, 1999). Samples with higher ratios may have been contaminated with exogenous carbon and bones with lower ratios were prone to degradation. Both, inadequate carbon contents and C/N ratios result in rejection of the analyzed samples from dating.

After analysis of the percent carbon content and C:N atomic ratio in bones, in the Poznań Radiocarbon Laboratory routine bone pretreatment procedure involves (Brock et al., 2010; Brown et al., 1988, Stanley, 1990):

- ABA pre-treatment,
- gelatinization of the sample,
- ultrafiltration of the collagen.

## 6. Results and discussion

$^{14}\text{C}$  dating results for the bones and wood fragments samples are given in Table 1 and 2, and calibrated  $^{14}\text{C}$  dates are shown in figure 5. A detailed interpretation of the research material is given below, in sub-chapters relating to particular archaeological sites. The archaeological context presented in table 1, was established on the basis of relative chronology made during the excavation. Till 2011 almost in all of the sites presented in this paper relative dating based on ceramic residue, stone objects or other artefacts has been made.

### 6.1 Suchy Las

$^{14}\text{C}$  dates collected from both features (animal bones) correspond relatively well with the conventional chronology determined on the basis of technical and decorative traits of pottery excavated at the site (table 1, 2; fig. 5). A rare agricultural tool discovered in one feature (24) or an imported graphite pottery found in another one can also be dated to the early Piast period,

namely the transition phase between D2/E1 phases (Łosiński & Rogosz, 1983, 1986) of the Early Middle Ages. Owing to the obtained radiocarbon dates, the dates known from written sources regarding the beginnings of the early medieval village of *Zuchilecz* (Suchy Las - the first one is supposed to have existed already in 1170), has partially been confirmed. The  $^{14}\text{C}$  dates from archaeological materials allow for the conclusion that an early medieval settlement site had existed in this place a bit earlier than historical dates suggest.

Site	Sample name	Material/ comments	Lab code	Archaeological context
Suchy Las	SLAS/ob24/35/2007	Animal bone/ 2.3%N 7.2%C	Poz-43114	a settlement site, phase D2 Early Middle Ages: 2 <sup>nd</sup> half of the 10 <sup>th</sup> century – 1 <sup>st</sup> half of the 11 <sup>th</sup> century;
	SLAS/ob26/37/2009	Animal bone/ 3.2%N 8.8%C	Poz-43115	a settlement site, phase E2 Early Middle Ages: end of 12 <sup>th</sup> - 1 <sup>st</sup> half of the 13 <sup>th</sup> century
Trzcielín	TRZ/ob64/49/2009	Animal bone/ 2.6%N 8.4%C	Poz-43113	a settlement site, Early Middle Ages (end of the 10 <sup>th</sup> -11 <sup>th</sup> /12 <sup>th</sup> century); a bloomery/rubbish pit
Snowidowo	SNOW/ob74/16/2009	Animal bone/ 2.4%N 7.4%C	Poz-43123	the Przeworsk culture, pre-Roman period 2 <sup>nd</sup> century BC - BC/AD); rubbish pit; probably two development phases
Zielęcín	ZIEL/ob6/4/2009	Animal bone/ 1.4%N 6.6%C	Poz-43119	a settlement site, phase A-B Early Middle Ages (end of 6 <sup>th</sup> -7 <sup>th</sup> century); half dugout
	ZIEL/ob7/5/2009	Animal bone/ 1.4%N 5.9%C	Poz-43120	
Łęki Wielkie	LEWIEL/ob12/4/2009	Animal bone/ 2.5%N 8.3%C	Poz-43121	a settlement site accompanying the stronghold, phase C Early Middle Ages (end of 9 <sup>th</sup> century to about 1 <sup>st</sup> half of the 10 <sup>th</sup> century); half dugout
Żerniki	ZERN/ob218/76/2009	Animal bone/ 1.2%N 4.7%C	Poz-43116	a settlement site, the Przeworsk culture (3 <sup>rd</sup> - 4 <sup>th</sup> century AD)
	ZERN/ob302/94/2009	Animal bone/ 1.3%N 5.7%C	Poz-43117	
Szczyrzykowo	SZCZ/ob56/40/2004	Wood - Pinus	Poz-43124	a settlement site, the Lusatian culture, Hallstatt period (7 <sup>th</sup> - 5 <sup>th</sup> century BC)
	SZCZ/ob52/36- 37/2004	Wood - Quercus	Poz-43125	a settlement site, Late Middle Ages (14 <sup>th</sup> century)

Table 1. The sample description together with the place of sample collection; Lab code: Poz – sample dated with the AMS technique in the Poznan Radiocarbon Laboratory; %N- percentage of nitrogen; %C – percentage of carbon in the sample.

Sample name	Lab code	<sup>14</sup> C age BP	Calibrated age AD	
			68%	95%
SLAS/ob24/35/2007	Poz-43114	1020±30	991 (68.2%) 1026	902 (1.9%) 915 969 (88.5%) 1045 1095 (4.1%) 1120 1141 (1.0%) 1148
SLAS/ob26/37/2009	Poz-43115	895±30	1049 (27.7%) 1085 1123 (9.5%) 1138 1151 (27.0%) 1188 1199 (3.9%) 1206	1040 (39.1%) 1110 1116 (56.3%) 1215
TRZ/ob64/49/2009	Poz-43113	975±30	1020 (32.9%) 1046 1092 (28.0%) 1121 1140 (7.3%) 1148	1014 (95.4%) 1155
SNOW/ob74/16/2009	Poz-43123	1685±30	266 (4.0%) 272 335 (64.2%) 408	257 (16.9%) 299 318 (78.5%) 422
ZIEL/ob6/4/2009	Poz-43119	1510±30	539 (68.2%) 600	435 (15.0%) 491 509 (1.2%) 518 529 (79.2%) 623
ZIEL/ob7/5/2009	Poz-43120	1235±30	694 (30.0%) 748 765 (29.8%) 820 842 (8.4%) 860	687 (95.4%) 879
LEWIEL/ob12/4/2009	Poz-43121	1100±30	897 (25.6%) 923 941 (42.6%) 985	887 (95.4%) 1014
ZERN/ob218/76/2009	Poz-43116	1750±30	242 (17.8%) 265 272 (50.4%) 335	216 (95.4%) 390
ZERN/ob302/94/2009	Poz-43117	1730±30	255 (68.2%) 345	240 (95.4%) 391
SZCZ/ob56/40/2004	Poz-43124	2625±30	815 BC (68.2%) 791 BC	836 BC (95.4%) 771 BC
SZCZ/ob52/36-37/2004	Poz-43125	580±30	1317 (46.0%) 1354 1389 (22.2%) 1408	1300 (63.4%) 1369 1381 (32.0%) 1419

Table 2. Results of <sup>14</sup>C dating. Lab code: Poz – sample dated with the AMS technique in the Poznan Radiocarbon Laboratory; Calibrated age from OxCal v4.1.7 (Bronk Ramsey 2010); Atmospheric data from Reimer et al., (2009).

## 6.2 Trzcielín

The data obtained from feature 64 (animal bone) in the interval 1014AD (95.4%) 1155AD – can prove that the process of early feudal dependencies formation: the central stronghold of Poznań and an accompanying production settlement site, began to emerge in this region of Wielkopolska much earlier than hitherto believed. This kind of relations prevailed already in the first half of the 11<sup>th</sup> century.

## 6.3 Snowidowo

The obtained date from the animal bone from feature 74 verify earlier hypotheses that we can distinguish between two developmental phases of the settlement site of the Przeworsk culture (see section 2.3 Snowidowo), namely a pre-Roman settlement site (from the 2<sup>nd</sup> century BC-BC/AD, on the basis of relative chronology), and a Late Roman settlement site (the period between 318 AD to 422 AD, on the basis of a <sup>14</sup>C date).

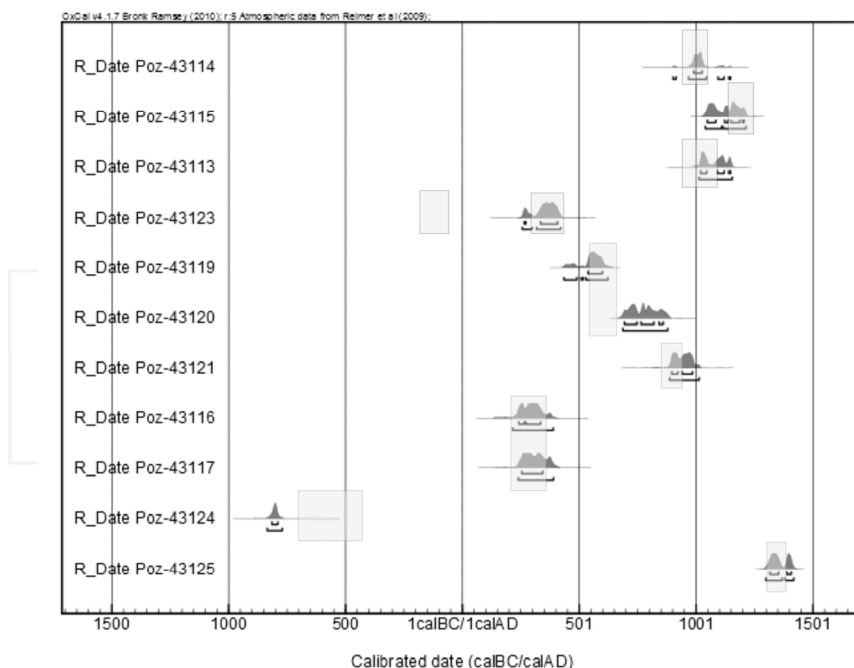


Fig. 5. Results of calibration in graphical form obtained with OxCal v4.1.7 (Bronk Ramsey, 2010; Reimer et al., 2009); the intervals of archaeological estimations are marked in grey color.

#### 6.4 Zielęcin

$^{14}\text{C}$  date obtained from feature 6 confirms the preliminary age estimations of the complex, whereas the other date, from an adjoining feature 7 is 'moved' at least one century in relation to the above mentioned chronology. It possibly results from the existence of two early medieval chronological phases of the settlement. The first one could have existed between the 6<sup>th</sup> -7<sup>th</sup> century, and the other functioned between the 7<sup>th</sup> -9<sup>th</sup> century. A standard (conventional) analysis of archaeological material did not capture the latter date. We also have to take into consideration that despite applied pretreatment the sample subject to radiocarbon dating could have been contaminated by carbon of a different origin.

#### 6.5 Łęki Wielkie

The obtained  $^{14}\text{C}$  date from feature 12 at the settlement (from 887 AD to 1014 AD) proved that, as it was expected on the basis of archaeological investigations, both settlement structures, namely a settlement accompanying the stronghold and the stronghold, functioned at the same time. Moreover, it seems that both settlement complexes were incorporated into the structures of the early Piast state in a peaceful way, which is also indirectly proven by the fact that survey excavations did not register any burnt layers either in the stronghold or in the features on the settlement site.

## 6.6 Żerniki

Two similar  $^{14}\text{C}$  dates from features registered on distant outskirts of the settlement prove that the excavated structures of the settlement site come from the same chronological period, namely from about 216 AD to about 390 AD. The result of radiocarbon dating was consistent with research expectation formulated in the phase of fieldwork. Owing to  $^{14}\text{C}$  dating, the final study on the material remains from this settlement will be devoid of speculations on the chronology of the majority of features that did not contain any artefacts.

## 6.7 Szczodrzykowo

The date obtained from wood from feature 52 is consistent with conventional dating determined in the course of analysis of potsherds from this feature. In case of dating the wood from feature 56 it may be concluded that preliminary established by archaeologists age ranges dating of this settlement complex should be corrected on the basis of radiocarbon dating. The reason is that the dating based on the characteristics of pottery (73 potsherds were registered) situated this feature in the Hallstatt period (between the 7th and 5th century BC). In this case, on the basis of radiocarbon dating, we should move the feature 'up' the chronological table of the Lusatian culture and date it to the times at least from 836 BC to 771 BC. Reassuming - for reliable dating of features such as the mentioned well of the Lusatian culture, it is necessary to acquire diverse material for dating and to compare the relative chronology with the results of isotope or other dating methods..

## 7. Conclusion

The radiocarbon method has a very wide application in various fields of science. On the basis of the presented results of the dating of bones and wood, we presented the use of this method in determining the chronology of archaeological sites. At the same time, the possibility of using various materials, in this case bones and wood, with a small quantity required for the dating of the fraction, makes it a valuable source of information for a comparison with the relative chronology.

The results of radiocarbon dating can help us verify the time intervals of given settlements or features established by archaeologists on the basis of the typology and decoration of excavated ornaments or pottery.

The comparison of the relative chronology with the results of  $^{14}\text{C}$  measurements enabled, e.g. for the site of Zielęcín, samples from feature 6 (Poz-43119), to confirm the archaeological expectations. The result of dating the sample from feature 7 (Poz-43120) from the same site did not provide final answers regarding the time period in which it functioned, because of discrepancy between relative chronology and radiocarbon dating results. Such an outcome may be interpreted as a recognition of another early medieval chronological phase of the settlement, but there is no archaeological evidence for this.

These results show, therefore, that in some cases, it is necessary to conduct further investigation or to select other materials from the same period for dating purposes, in order to verify the chronology of a given feature, e.g. in case of Szczodrzykowo (Poz-43124) or Zielęcín (Poz-43120). In general, most of the obtained results allowed positive verification of the time intervals of functioning of the archaeological sites determined on the basis of relative chronology.

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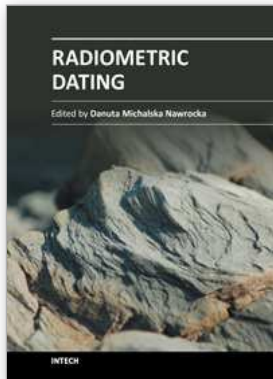
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This book explores a diversity of topics related to radiometric dating, with particular emphasis on the method of radiocarbon dating and a cross-check of its results with luminescence measurements. Starting from the chapter on Methodology the book includes, among other topics, the description of the problem of preparation of samples for  $^{14}\text{C}$  measurement, a wide application of the radiocarbon method and a comparison of results obtained by various methods, including the radiocarbon method, the method of OSL, TL and palynology. The issue of radiocarbon dating of mortars and plasters is thoroughly discussed in the book. Chapter Two, Applications, and Three, Luminescence and Radiocarbon Measurements, provide examples of the application of the radiocarbon method in the study of archaeological, geological sites, from the analysis of soils, loesses, to the study of organic deposits filling the depressions in the Morasko Meteorite Nature Reserve. A wide range of studies reveals the great potential of the radiocarbon method, and the presented papers reflect interdisciplinary research.

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