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^{14}C CHRONOLOGY OF MESOLITHIC SITES FROM POLAND AND THE BACKGROUND OF ENVIRONMENTAL CHANGES

Anna Pazdur[1,2] • Mariusz Fogtman[1] • Adam Michczyński[1] • Jacek Pawlyta[1] • Mirosław Zając[3]

ABSTRACT. Mesolithic sites in modern Poland are mainly located in the southern part of the country. Radiocarbon dating of organic material, such as charcoals, wood, and peat, provide a time frame of human settlements in those regions, and dating of speleothems and peat formations provide information on climatic conditions and the timing of climatic change in the region. Here, we present the results of calibrated ^{14}C ages from 3 main Mesolithic sites: Glanów, Chwalim, and Całowanie. Summary probability density distributions of the calendar ages were obtained, and time ranges were ascribed to the cultures in conjunction with archaeological information. These distributions also reveal the changes in human settlement.

INTRODUCTION

At the turn of the IX and VIII millennium BC (Preboreal period), climatic conditions in Poland became similar to the present time. During this early stage of the Holocene, climatic conditions were moderating, as evidenced in the Atlantic maximum level which took place at the V millennium BC. This Pleistocene/Holocene transitional period was characterized by the new ecological circumstances which triggered a movement of human settlements to the northern parts of Poland. The main reason for the migration was probably to search for new resources/food supplies. This new settlement initiated Mesolithic cultures in these regions and defines the Mesolithic for the region as a period that lasted from the beginning of the Holocene to the first appearance of Neolithic people in Poland at the V millennium BC. The onset of the Mesolithic period is also related to the appearance of an entirely new population of reindeer hunters that migrated to Poland from the northwestern part of the European Plain.

The Mesolithic was, generally, a period of cultural stabilization, and cultural differences between individual groups of people were relatively insignificant. The differences were determined on the basis of the technical variety of flint tool production. Mesolithic tools, found mainly in peat bogs, consist of bone, horn, and wood elements. Bones and horns were used in the production of the harpoons, spear points, fishhooks, etc. Wood was used mainly in the production of boats and oars. However, during the Mesolithic, flint tools were becoming less common. Most of the tools were in the form of stone fixed on the top of bone. Other tools present, though rare finds, were designed for scratching and scraping, such as a prototype axe used for cutting and processing trees and wood (Godłowski et al. 1983).

The earliest Mesolithic settlements in Poland associated with the sites studied in this project were connected with 3 successive cultures: Komornica, early Mesolithic to VI millennium (Gąssowski 1985); Janislawice, VII and VI millennium BC to the end of the Mesolithic (Gąssowski 1985); and Chojnicko-Pieńkowska, persisting to the end of the Mesolithic (Gąssowski 1985). These successive cultures specialized in shaved flint tools; in the Janisławice sites, decorations made from wild boar tusks are found in addition to finished tools of flint, horn, and bone. The last successor, the Chojnicko-Pieńkowska culture, specialized in hunting but were also known to fish (Gąssowski 1985).

[1]Silesian University of Technology, Department of Radioisotopes, 44-100 Gliwice, Krzywoustego 2, Poland.
[2]Corresponding author. Email: pazdur@zeus.polsl.gliwice.pl.
[3]Archeological Museum in Kraków, 31-002 Kracow, Senacka 3, Poland.

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During the Mesolithic period, the exploitation of the surrounding environment, which lasted for dozens of millenniums, ended. Cultures were now mainly concentrated on improvements of tools and arms for hunting and defense. The proceeding new Mesolithic economy depended on improved climatic conditions and may have allowed greater cultural development of improved living conditions. This period was marked by the development of clothing production, new building and heating technologies, and more sophisticated food processing (i.e. removal of toxic substances through boiling and roasting), though the significant source of food was still hunting and gathering (Gąssowski 1985).

The least-known issue of the Mesolithic is the character of its social structure. The problem lies in the fact that the Mesolithic cultures were disrupted by subsequent cultures and, thus, there are some problems in identifying true Mesolithic cultural characteristics.

It is thought that the development of these cultures through time was especially dependent upon improving climatic conditions (Godłowski et al. 1983), which we examine in this paper. The Mesolithic period in Poland can be subdivided into 3 climatic stages. The Preboreal (about 9950 BC to 8570 BC) was characterized by a moderately warm climate. Forests were dominated by pine, and mild climatic conditions favored the formation of brown soils (Godłowski et al. 1983). The Boreal (about 8570 BC to 7530 BC) was moderately warm and humid. The black earth and bog soils were formed and the forests were enriched by birch (Godłowski et al. 1983). The Atlantic period, referred to as the climatic optimum of the Holocene (about 7530 BC to about 3960 BC), was warmer than the contemporary climate, with the average annual temperature about 2 °C warmer than the present. These conditions aided the significant growth of vegetation and an increase of the global sea level by up to 2 m (Godłowski et al. 1983). Two climatic eras of the Holocene followed the Mesolithic period. The Subboreal (about 3960 BC to 460 BC) was warm with increased humidity, and the Subatlantic (about 460 BC to AD 1810) had climatic conditions similar to the present climate (Pazdur 1987; Gąssowski 1985).

SITE LOCATIONS AND MATERIALS

The Mesolithic sites in Poland which are included in this study are mainly concentrated in the southern part of the country. The main sites of interest are Glanów, Całowanie, and Chwalim (Figure 1).

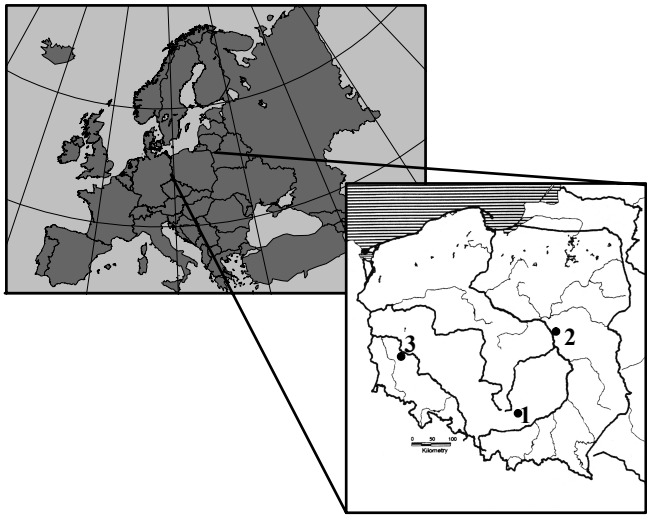

Figure 1 Map of Poland and the location of Mesolithic sites: 1: Glanów 3; 2: Calowanie; 3: Chwalim.

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The Glanów site 3 (19°47′W, 50°18′N) is located about 30 km northwest of Kraków. This site is situated on a sandy hill on the left side of the Dłubnia River bank. The study area of Glanów site 3 is about 775 m^2 and is described in detail by Zając (2001), who in 1995–99 lead an archeological excavation of the site. Up to 41 ^{14}C dates have been obtained on charcoal samples, most of which range in age from the Early to Late Mesolithic. These ages are supported by archaeological finds (e.g. flint tools and pottery) corresponding to the Mesolithic. Some additional ^{14}C ages correspond to later cultures such as the Lengyel, Mierzanowice and Lusatian, and the Roman period, which were also in agreement with associated artifacts (Zając 2001).

The Chwalim site (15°46′W, 52°08′N) is situated on the sandy-gravel bed of the Gnila Obra River near Poznań. A preliminary geological stratigraphy of the Chwalim site has been reconstructed by Kobusiewicz et al. (1993) and Kobusiewicz (1999), wherein both a clear stratigraphic section and a section with less distinct layering is described. Several flints and bones of deer, elk, and bison were found in the record with the distinct stratigraphy, and numerous flints, burnt stones, and pottery were present in the section with indistinct layering. Charcoal samples are located together with artifacts in the peat bog. There were 11 charcoal samples, but only three belong to the Mesolithic period (Figure 2). The artifacts found allow one to identify the archaeological cultures. Charcoal samples were dated and the results were compared with the obtained archaeological periods as determined by artifact style. The youngest of the 3 samples came from the palinological profile and had no archaeological significance (Figure 2). The remaining samples belong to Paraneolithic period.

The Całowanie site (21°17′W, 52°01′N) is situated on the sandy island in a peat bog of the Vistula River bed. The area of this site is about 6000 m^2. The distinct geological stratigraphy of the site assisted in the association of the ages of charcoal samples with specific cultural layers. The stratigraphic distinction in the sections at this site was defined by 11 archaeological levels which included artifacts such as flint tools and datable materials such as wood. From this site, 32 samples were dated and correlation between ^{14}C ages and archaeological levels were described by Schild (1975, 1989, 1996, 1998, 2001) and Schild et al. (1999).

All of the samples selected for ^{14}C dating from the Mesolithic sites described above consisted of charcoals and were, except for specific samples, collected by the authors. For Glanów site 3, the charcoal samples were collected by M Zając, who researched this site in 1995–1999. Samples from the Chwalim site were investigated by Kobusiewicz in 1975–1979. In the Całowanie site, charcoals were collected and submitted by Schild.

METHODS

Pretreatment and CO_2 production was done in the Gliwice Radiocarbon Laboratory. Charcoal samples were chemically pretreated with a 1% solution of HCl for 1 hr in 80 °C to remove contamination by carbonates. The sample was then washed in distilled water to neutral pH and dried at 80 °C for 20 hr. In the Gliwice lab, the 0.5 M NaOH treatment for charcoal samples is omitted because of the significant loss of mass that follows a base treatment. Samples were combusted and the resultant CO_2 was purified according to the standard procedure used in the Gliwice lab. The measurement of ^{14}C concentration was carried out in gas proportional counters (Pazdur and Pazdur 1986; Pazdur et al. 2000).

RESULTS

We have collected a total of 84 ^{14}C dates, of which 67 were obtained in the Gliwice lab. These include 41 ^{14}C dates from Glanów site 3, 11 ages from the Chwalim site, and 32 dates from the

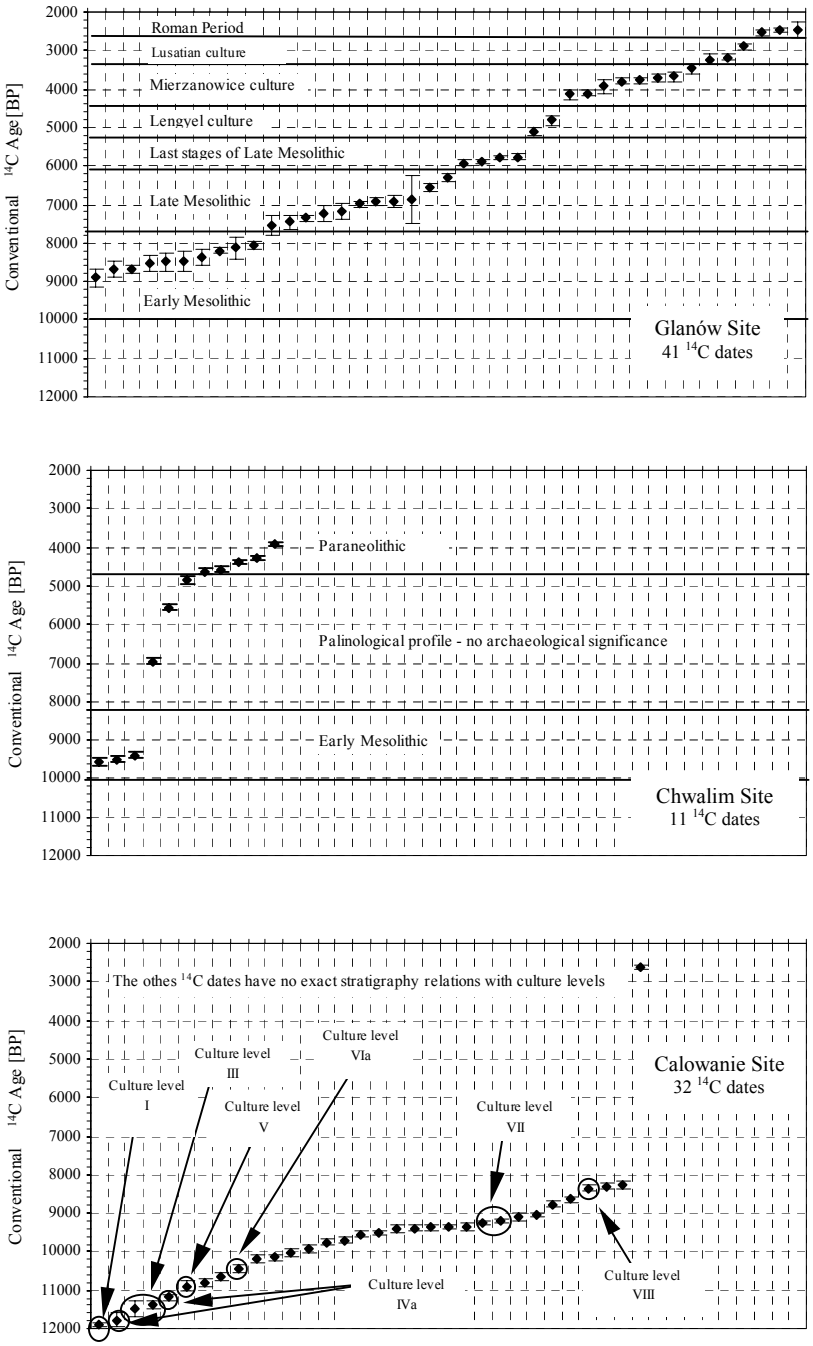

Figure 2 Cumulative probability density distributions of ^{14}C conventional dates from Mesolithic sites in Poland.

Całowanie site (Figure 2). For the 11 samples from the Chwalim site, 4 charcoal samples were dated in the Laboratory of the Zentralinstitut für Alte Geschichte und Archäologie, Akademie der Wissenschaften der DDR in Berlin (Bln). The samples from the Całowanie site were dated at the Center for

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Accelerator Mass Spectrometry at Lawrence Livermore National Laboratory (CAMS), USA, the Center of Isotope Research, University of Groningen, the Netherlands (GrN), and at Gliwice. Description of the samples and the ^{14}C dating results from Glanów 3, Chwalim, and Całowanie are given in Tables 1, 2, and 3, respectively, and illustrated in Figure 2.

The ^{14}C dates were calibrated using the OxCal v3.8 calibration program (Ramsey 2002). Results of the calibration procedure, represented by probability intervals with 68% and 95% confidence, are shown (Tables 1, 2, and 3).

FREQUENCY DISTRIBUTIONS OF CALENDAR AGES

The division of ^{14}C dates into archaeological cultures was carried out on the basis of charcoal dating and archaeological determinations based on the cultural style of associated artifacts in each of the sites at Glanów, Chwalim, and Całowanie. Calibration of the dates was then completed for each of the groupings to obtain the calendar age ranges. Figures 3, 4, and 5 show the cumulative probability density distributions of calibrated ^{14}C ages and the assignment of the results into archaeological cultures at the Glanów, Chwalim, and Całowanie sites.

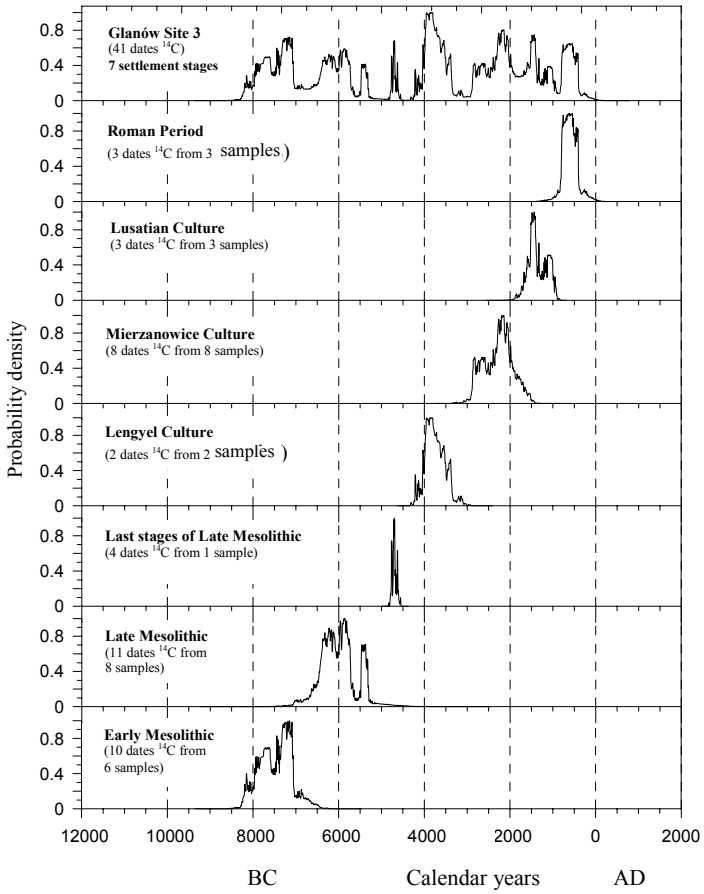

Figure 3 Cumulative probability density distributions of calibrated ^{14}C ages with the division into archaeological cultures from Glanów site 3.

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Table 1 Description (name, species [if known], institution, collector, lab nr, aggregation) and conventional and calibrated ages of the samples from Glanów Site 3 (19°47′W, 50°18′N). Age range has been determined with confidence levels of 68% and 95% using the OxCal v3.8 program. The numbers in brackets are the percent of age range in the total probability density distribution of the calibrated age. The system of aggregations on the site are shown in Figure 6.

Name, sample description	Lab nr	Aggregation	^{14}C age (BP)	Age range (68%) (cal AD, BC)	Age range (95%) (cal AD, BC)
1. Glanów G3/97/5948 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-17140	NW	8910 ± 250	8300–7650 BC (68.2%)	8800–7400 BC (95.4%)
2. Glanów G3/97/5586 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-18160	E	8690 ± 210	8200–7500 BC (68.2%)	8300–7200 BC (95.4%)
3. Glanów G3/97/6133 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-10831	NW	8670 ± 110	7940–7930 BC (1.2%) 7920–7900 BC (2.8%) 7880–7860 BC (1.9%) 7830–7580 BC (62.3%)	8200–7500 BC (95.4%)
4. Glanów G3/97/8822 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-30016	NE	8530 ± 210	7950–7300 BC (67.4%) 7250–7200 BC (0.8%)	8300–7000 BC (95.4%)
5. Glanów G3/97/5004 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-18161	E	8490 ± 220	7950–7150 BC (68.2%)	8300–7000 BC (95.4%)
6. Glanów G3/96/3683 Archeological Museum in Kraków (Zając 1996)	Gd-10749	S	8490 ± 270	7950–7050 BC (68.2%)	8300–6800 BC (95.4%)
7. Glanów G3/97/5303 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-17149	E	8360 ± 210	7600–7050 BC (68.2%)	8000–6700 BC (95.4%)
8. Glanów G3/96/3718 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1996)	Gd-12413	S	8200 ± 80	7320–7070 BC (68.2%)	7480–7050 BC (95.4%)
9. Glanów G3/97/8609 Archeological Museum in Kraków, (Zając 1997)	Gd-13003	NE	8130 ± 280	7500–6700 BC (68.2%)	7800–6400 BC (95.4%)
10. Glanów G3/97/4983 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-11413	E	8050 ± 100	7180–7150 BC (3.3%) 7140–6800 BC (62.3%) 6790–6770 BC (2.6%)	7350–6650 BC (95.4%)
11. Glanów G3/96/4035 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1996)	Gd-16149	S	7550 ± 250	6650–6050 BC (68.2%)	7100–5900 BC (95.4%)
12. Glanów G3/97/7168 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-13010	NW	7460 ± 200	6480–6070 BC (68.2%)	6750–5800 BC (95.4%)
13. Glanów G3/97/7744 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-11444	E	7360 ± 100	6380–6310 BC (13.9%) 6300–6280 BC (2.1%) 6270–6080 BC (52.2%)	6420–6020 BC (95.4%)
14. Glanów G3/96/3349 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1996)	Gd-13007	S	7250 ± 210	6380–6310 BC (8.2%) 6300–6280 BC (1.3%) 6270–5970 BC (52.8%) 5960–5910 BC (5.8%)	6500–5700 BC (95.4%)

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Table 1 Description (name, species [if known], institution, collector, lab nr, aggregation) and conventional and calibrated ages of the samples from Glanów Site 3 (19°47′W, 50°18′N). Age range has been determined with confidence levels of 68% and 95% using the OxCal v3.8 program. The numbers in brackets are the percent of age range in the total probability density distribution of the calibrated age. The system of aggregations on the site are shown in Figure 6. *(Continued)*

Name, sample description	Lab nr	Aggregation	^{14}C age (BP)	Age range (68%) (cal AD, BC)	Age range (95%) (cal AD, BC)
15. Glanów G3/97/9000 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-30015	NE	7180 ± 190	6230–5870 BC (65.9%) 5860–5840 BC (2.3%)	6450–5700 BC (95.4%)
16. Glanów G3/97/8995 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-10834	NE	6990 ± 90	5980–5940 BC (12.1%) 5920–5770 BC (56.1%)	6030–5710 BC (95.4%)
17. Glanów G3/97/8611 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-15389	NE	6940 ± 110	5980–5950 BC (5.1%) 5910–5720 BC (63.1%)	6020–5630 BC (68.2%)
18. Glanów G3/97/8605 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-16148	NE	6930 ± 170	5990–5940 BC (8.2%) 5930–5660 BC (60.0%)	6200–5450 BC (95.4%)
19. Glanów G3/96/3746 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1996)	Gd-14008	S	6870 ± 640	6500–5000 BC (68.2%)	7300–4300 BC (95.4%)
20. Glanów G3/97/7368 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-15394	E	6570 ± 90	5620–5470 BC (66.2%) 5440–5420 BC (2.0%)	5670–5360 BC (95.4%)
21. Glanów G3/97/7387 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-11442	E	6300 ± 90	5370–5200 BC (52.2%) 5180–5140 BC (8.5%) 5120–5080 BC (7.5%)	5480–5040 BC (95.4%)
22. Glanów G3/97/7757(1) *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-12433	E	5920 ± 70	4910–4870 BC (6.5%) 4860–4710 BC (61.7%)	4960–4590 BC (95.4%)
23. Glanów G3/97/7757(2) *Coniferae indet.*, Archeological Museum in Kraków (Zając 1997)	Gd-11658	E	5870 ± 60	4840–4820 BC (2.7%) 4810–4670 BC (60.8%) 4640–4620 BC (4.7%)	4910–4870 BC (1.6%) 4860–4580 BC (91.7%) 4570–4550 BC (2.0%)
24. Glanów G3/97/7757(3) Unidentified, Archeological Museum in Kraków (Zając 1997)	Gd-11659	E	5790 ± 60	4720–4550 BC (68.2%)	4780–4490 BC (95.4%)
25. Glanów G3/97/7790 *Coniferae indet.*, Archeological Museum in Kraków (Zając 1997)	Gd-12432	E	5760 ± 80	4710–4520 BC (66.0%) 4510–4500 BC (2.2%)	4800–4450 BC (94.4%) 4420–4400 BC (1.0%)
26. Glanów G3/97/7292 *Pinus sylvestris*, *Quercus sp.* Archeological Museum in Kraków (Zając 1997)	Gd-10837	NE	5110 ± 110	4040–4020 BC (3.8%) 4000–3770 BC (64.4%)	4250–3650 BC (95.4%)
27. Glanów G3/96/3783 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1996)	Gd-17147	S	4820 ± 150	3770–3490 BC (53.2%) 3470–3370 BC (15.0%)	4000–3300 BC (92.0%) 3250–3100 BC (3.4%)
28. Glanów G3/97/6594 Pinus sylvestris, *Sambucus sp.*, *Corylus avellana*, Archeological Museum in Kraków (Zając 1997)	Gd-13008	NW	4140 ± 140	2890–2560 BC (64.2%) 2530–2490 BC (4.0%)	3100–2250 BC (95.4%)

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Name, sample description	Lab nr	Aggregation	^{14}C age (BP)	Age range (68%) (cal AD, BC)	Age range (95%) (cal AD, BC)
29. Glanów G3/97/7174 *Quercus sp.* Archeological Museum in Kraków, (Zając 1997)	Gd-12430	NW	4110 ± 70	2870–2800 BC (16.8%) 2760–2570 BC (50.4%) 2510–2500 BC (1.0%)	2880–2490 BC (95.4%)
30. Glanów G3/97/8112 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-30014	NE	3930 ± 170	2850–2800 BC (1.2%) 2700–2100 BC (67.0%)	2900–1950 BC (95.4%)
31. Glanów G3/97/7694 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-11445	E	3790 ± 90	2400–2370 BC (3.7%) 2350–2120 BC (55.9%) 2090–2040 BC (8.6%)	2500–1950 BC (95.4%)
32. Glanów G3/97/7177 *Pinus sylvestris*, *Quercus sp.* Archeological Museum in Kraków (Zając 1997)	Gd-10826	NE	3780 ± 70	2330–2320 BC (1.1%) 2310–2120 BC (57.3%) 2090–2040 BC (9.8%)	2460–2020 BC (94.4%) 2000–1980 BC (1.0%)
33. Glanów G3/97/5805 *Quercus sp.* Archeological Museum in Kraków (Zając M 1997)	Gd-15385	NW	3720 ± 90	2290–2250 BC (6.0%) 2240–1970 BC (62.2%)	2500–1800 BC (95.4%)
34. Glanów G3/96/3611 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1996)	Gd-10754	S	3670 ± 140	2290–1870 BC (66.8%) 1840–1820 BC (1.4%)	2500–1650 BC (95.4%)
35. Glanów G3/97/6548 *Pinus sylvestris*, *Quercus sp.* Archeological Museum in Kraków (Zając 1997)	Gd-14011	NE	3460 ± 130	1950–1600 BC (68.2%)	2150–1450 BC (95.4%)
36. Glanów G3/97/7942 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-14013	NE	3240 ± 130	1690–1390 BC (67.4%) 1330–1320 BC (0.8%)	1900–1100 BC (95.4%)
37. Glanów G3/97/7087 *Pinus sylvestris*, *Corylus avellana*, Archeological Museum in Kraków, (Zając 1997)	Gd-10833	NW	3170 ± 70	1520–1380 BC (64.5%) 1340–1320 BC (3.7%)	1620–1260 BC (95.4%)
38. Glanów G3/97/7672 *Pinus sylvestris*, *Corylus avellana*, Archeological Museum in Kraków (Zając 1997)	Gd-12121	E	2900 ± 60	1220–990 BC (68.2%)	1290–910 BC (95.4%)
39. Glanów G3/97/8312 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-15383	NW	2530 ± 80	800–750 BC (13.4%) 730–520 BC (54.8%)	810–400 BC (95.4%)
40. Glanów G3/97/6088 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-12119	NW	2470 ± 60	770–680 BC (23.0%) 670–610 BC (16.6%) 600–510 BC (22.3%) 470–450 BC (2.6%) 440–410 BC (3.7%)	780–400 BC (95.4%)
41. Glanów G3/97/8533 *Pinus sylvestris*, Archeological Museum in Kraków (Zając 1997)	Gd-13004	NE	2460 ± 210	850–350 BC (67.0%) 300–250 BC (1.2%)	1100 BC–beginning AD

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Table 2 Description (name, material, institution, collector, lab nr) and conventional and calibrated ages of the samples from the Chwalim site (15°46′W, 52°08′N). Age range has been determined with confidence levels of 68% and 95% using the OxCal v3.8 program. The numbers in brackets are the percent of age range in the total probability density distribution of the calibrated age.

Name and sample description	Lab nr	^{14}C age (BP)	Age range (68%) (cal AD, BC)	Age range (95%) (cal AD, BC)
1. Chwalim WKT III/79-2, charcoal, PAN in Poznań,Kobusiewicz M, 1979	Gd-1164	9565 ± 90	9150–8790 BC (68.2%)	9250–8600 BC (95.4%)
2. Chwalim WKT I/76-2 charcoal	Bln-1766	9500 ± 75	9120–8990 BC (29.2%) 8910–8870 BC (4.7%) 8860–8720 BC (28.7%) 8710–8690 BC (3.6%) 8660–8640 BC (2.0%)	9200–8600 BC (95.4%)
3. Chwalim WKT III/77-2 wood, PAN in Poznań, Kobusiewicz M 1979	Gd-1165	9385 ± 75	8780–8760 BC (1.7%) 8750–8540 BC (64.7%) 8490–8480 BC (1.7%)	9150–8950 BC (6.3%) 8900–8300 BC (89.1%)
4. Chwalim WKT I/77-2a(1) peat, PAN in Kraków, Wasylikowa 1977 palinological profile	Gd-6342	6950 ± 100	5970–5950 BC (5.2%) 5910–5720 BC (63.0%)	6010–5660 BC (95.4%)
5. Chwalim WKT I/77-2a(2) peat, PAN in Kraków, Wasylikowa 1977 palinological profile	Gd-6366	5550 ± 100	4500–4320 BC (60.9%) 4290–4250 BC (7.3%)	—
6. Chwalim WKT I/77-2a(3) peat, PAN in Kraków, Wasylikowa 1977 palinological profile	Gd-6449	4870 ± 100	3780–3620 BC (49.1%) 3600–3520 BC (19.1%)	3950–3350 BC (95.4%)
7. Chwalim WKT II/79-4,5c charcoal, PAN in Poznań, Kobusiewicz M, 1979	Gd-1176	4630 ± 70	3620–3600 BC (1.8%) 3530–3340 BC (65.0%) 3150–3140 BC (1.3%)	3650–3100 BC (95.4%)
8. Chwalim WKT I/77-4 peat, PAN in Kraków, Wasylikowa K, 1977	Gd-5831	4570 ± 60	3500–3460 BC (7.9%) 3380–3310 BC (22.8%) 3240–170 BC (20.1%) 3160–3100 BC (17.4%)	3520–3410 BC (16.0%) 3390–3080 BC (79.4%)
9. Chwalim WKT I/77-4(1) charcoal	Bln-2018	4375 ± 50	3090–3060 BC (6.2%) 3030–2910 BC (62.0%)	3310–3230 BC (5.2%) 3110–2880 BC (90.2%)
10. Chwalim WKT I/77-4(2) charcoal	Bln-2019	4280 ± 45	3010–2990 BC (2.1%) 2930–2870 BC (61.0%) 2810–2780 BC (5.2%)	3020–2860 BC (80.6%) 2810–2750 BC (11.8%) 2730–2700 BC (3.0%)
11. Chwalim WKT II/76-4 wood	Bln-1767	3900 ± 50	2470–2300 BC (68.2%)	2560–2540 BC (1.0%) 2500–2200 BC (94.4%)

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Name, sample description	Lab nr	Culture level[a]	^{14}C age (BP)	Age range (68%) (cal AD, BC)	Age range (95%) (cal AD, BC)
1. Całowanie IX/3c charcoal, PAN in Warsaw (Schild)	CAMS-20890	1,*2*,*3*, *4a*,*4b*[1]	11,890 ± 70	12,140–11,850 BC (62.9%) 11,750–11,690 BC (5.3%)	13,300–12,700 BC (11.8%) 12,400–11,500 BC (83.6%)
2. Całowanie IX/5a(1) charcoal, PAN in Warsaw (Schild)	Gd-2882	4a	11,770 ± 160	12,100–11,500 BC (68.2%)	13,300–12,800 BC (7.7%) 12,400–11,200 BC (87.7%)
3. Całowanie X/6(1) charcoal, PAN in Warsaw (Schild 1968)	Gd-4165	3	11,470 ± 200	11,900–11,700 BC (12.5%) 11,650–11,200 BC (55.7%)	12,200–10,900 BC (95.4%)
4. Całowanie X/6(2) charcoal, PAN in Warsaw (Schild)	GrN-5967	3	11,380 ± 95	11,500–11,230 BC (68.2%)	11,850–11,700 BC (10.0%) 11,600–11,050 BC (85.4%)
5. Całowanie IX/5a(2) charcoal, PAN in Warsaw (Schild)	GrN-5410	4a	11,190 ± 65	11,390–11,310 BC (14.2%) 11,260–11,060 BC (54.0%)	11,800–11,750 BC (1.3%) 11,500–10,950 BC (94.1%)
6. Całowanie IX/5c charcoal, PAN in Warsaw (Schild 1969)	Gd-2723	*5*	10,900 ± 130	11,190–11,110 BC (13.6%) 11,100–10,890 BC (54.6%)	11,250–10,650 BC (95.4%)
7. Całowanie VII/6 charcoal, PAN in Warsaw (Schild)	GrN-5253	—	10,820 ± 90	11,050–10,860 BC (56.5%) 10,780–10,710 BC (11.7%)	11,200–10,650 BC (95.4%)
8. Całowanie III/6 charcoal, PAN in Warsaw (Schild)	GrN-4966	—	10,660 ± 100	10,950–10,670 BC (56.9%) 10,520–10,450 BC (11.3%)	11,050–10,350 BC (94.0%) 10,300–10,200 BC (1.4%)
9. Całowanie IX/8 charcoal, PAN in Warsaw (Schild)	GrN-5409	6a	10,455 ± 90	10,850–10,750 BC (5.9%) 10,700–10,350 BC (53.8%) 10,300–10,150 BC (8.5%)	10,900–10,000 BC (95.4%)
10. Całowanie VI/XI/7a charcoal, PAN in Warsaw (Schild 1967)	Gd-5202	—	10,180 ± 100	10,350–10,300 BC (1.1%) 10,200–9600 BC (65.3%) 9550–9450 BC (1.9%)	10,400–9300 BC (95.4%)
11. Całowanie VII/9b(1) charcoal, PAN in Warsaw (Schild 1983)	Gd-1648	*6b, 6c*	10, 140 ± 80	10,050–9400 BC (68.2%)	10,400–9350 BC (95.4%)
12. Całowanie VII/9b(2) wood, PAN in Warsaw (Schild 1983)	Gd-2147	*6b, 6c*	10,030 ± 120	9800–9300 BC (68.2%)	10,400–9200 BC (95.4%)
13. Całowanie III/9a charcoal, PAN in Warsaw (Schild R)	GrN-5254	*6c*	9935 ± 110	9680–9670 BC (0.9%) 9610–9510 BC (17.4%) 950–9240 BC (49.9%)	10,050–9200 BC (95.4%)

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Name, sample description	Lab nr	Culture level[a]	^{14}C age (BP)	Age range (68%) (cal AD, BC)	Age range (95%) (cal AD, BC)
14. Całowanie VII/9b(3) wood, PAN in Warsaw (Schild 1983)	Gd-1662	6b, 6c	9750 ± 80	9290–9130 BC (60.0%) 8990–8940 BC (8.2%)	9400–8800 BC (95.4%)
15. Całowanie VII/11b(1) wood, PAN in Warsaw (Schild 1966)	Gd-1717	6c, 7	9700 ± 80	9250–9110 BC (45.1%) 9000–8910 BC (20.4%) 8880–8860 BC (2.6%)	9280–8800 BC (95.4%)
16. Całowanie VI/IX/7a charcoal, PAN in Warsaw (Schild)	GrN-5255	—	9550 ± 85	9140–8980 BC (32.8%) 8940–8780 BC (32.6%) 8770–8740 BC (2.9%)	9250–8600 BC (95.4%)
17. Całowanie 11a(1) charred plants, PAN in Warsaw (Schild)	CAMS-20867	*7, 8*	9510 ± 70	9120–8990 BC (31.1%) 8910–8870 BC (6.3%) 8860–8720 BC (27.7%) 8710–8690 BC (2.3%) 8660–8650 BC (0.8%)	9200–8600 BC (95.4%)
18. Całowanie IX/11b charcoal, PAN in Warsaw (Schild 1969)	Gd-2734	*6a, 6b, 6c, 7, 8*	9410 ± 110	9150–9000 BC (10.5%) 8850–8450 BC (57.7%)	9150–8300 BC (95.4%)
19. Całowanie 9b charred plants, PAN in Warsaw (Schild)	CAMS-20870	*6c*	9390 ± 70	8750–8550 BC (68.2%)	9150–9000 BC (6.1%) 8900–8300 BC (89.3%)
20. Całowanie 11b(1) wood, PAN in Warsaw (Schild 1966)	Gd-1721	*6a, 6b, 6c, 7, 8*	9380 ± 80	8790–8760 BC (2.4%) 8750–8540 BC (63.3%) 8500–8470 BC (2.5%)	9150–8950 BC (6.5%) 8900–8300 BC (88.9%)
21. Całowanie 11b(2) wood, PAN in Warsaw (Schild 1966)	Gd-1719	*6a, 6b, 6c, 7, 8*	9370 ± 60	8740–8550 BC (67.3%) 8490–8480 BC (0.9%)	9100–9000 BC (1.0%) 8800–8300 BC (94.4%)
22. Całowanie 11b(3) wood, PAN in Warsaw (Schild 1966)	Gd-2198	*6a, 6b, 6c, 7, 8*	9350 ± 100	8750–8450 BC (67.4%) 8350–8340 BC (0.8%)	9150–8950 BC (5.3%) 8900–8250 BC (90.1%)
23. Całowanie VII/11b(2) charcoal, PAN in Warsaw (Schild)	GrN-5251	7, *8*	9250 ± 55	8560–8410 BC (51.4%) 8400–8330 BC (16.8%)	8610–8290 BC (95.4%)
24. Całowanie VII/11b(3) charcoal, PAN in Warsaw (Schild)	GrN-5442	7, *8*	9200 ± 75	8530–8500 BC (3.9%) 8480–8290 BC (64.3%)	8610–8270 BC (95.4%)

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Table 3 Description (name, material, institution, collector, lab nr, culture level) and conventional and calibrated ages of the samples from the Całowanie site (21°17′W, 52°01′N). Age range has been determined with confidence levels of 68% and 95% using the OxCal v3.8 program. The numbers in brackets are the percent of age range in the total probability density distribution of the calibrated age. *(Continued)*

Name, sample description	Lab nr	Culture level[a]	^{14}C age (BP)	Age range (68%) (cal AD, BC)	Age range (95%) (cal AD, BC)
25. Całowanie 11b(4) wood, PAN in Warsaw (Schild 1983)	Gd-2149	6a, 6b, 6c, 7, 8	9080 ± 100	8520–8510 BC (0.7%) 8480–8200 BC (66.3%) 8040–8020 BC (1.2%)	8600–7950 BC (95.4%)
26. Całowanie VII/11b(4) wood, PAN in Warsaw (Schild 1966)	Gd-3041	6a, 6b, 6c, 7, 8	9030 ± 50	8290–8215 BC (68.2%)	8410–8390 BC (1.1%) 8300–8160 BC (82.3%) 8140–8080 BC (4.1%) 8050–7960 BC (7.9%)
27. Całowanie 11a(2) wood, PAN in Warsaw (Schild 1983)	Gd-1667	*6a, 6b, 6c, 7, 8*	8780 ± 80	8200–8050 BC (4.9%) 8000–7650 BC (63.3%)	8250–7600 BC (95.4%)
28. Całowanie 11a(3) wood, PAN in Warsaw (Schild 1983)	Gd-1668	*6a, 6b, 6c, 7, 8*	8640 ± 80	7760–7580 BC (68.2%)	7950–7540 BC (95.4%)
29. Całowanie IX/11a charcoal, PAN in Warsaw (Schild)	GrN-5966	*7, 8*	8360 ± 75	7530–7320 BC (68.2%)	7580–7290 BC (85.8%) 7270–7240 BC (2.8%) 7230–7180 BC (6.8%)
30. Całowanie 11a(4) wood, PAN in Warsaw (Schild 1983)	Gd-1670	*6a, 6b, 6c, 7, 8*	8300 ± 70	7520–7500 BC (2.6%) 7480–7300 BC (55.8%) 7230–7180 BC (9.8%)	7530–7130 BC (94.0%) 7100–7080 BC (1.4%)
31. Całowanie 11a(5) charred cones, PAN in Warsaw (Schild 1983)	Gd-2146	*6a, 6b, 6c, 7, 8*	8270 ± 100	7480–7170 BC (66.1%) 7160–7140 BC (2.1%)	7530–7070 BC (95.4%)
32. Całowanie 11a(6) wood from post, PAN in Warsaw (Schild 1983)	Gd-2610	younger than 8	2610 ± 40	830–780 BC (65.7%) 775–765 BC (2.5%)	900–870 BC (1.4%) 840–750 BC (83.6%) 690–660 BC (4.2%) 640–590 BC (4.4%) 580–550 BC (1.8%)

[a]Plain numbers: the assignation of ^{14}C date to culture level is certain
Italic numbers: the assignation of ^{14}C date to culture level is uncertain.

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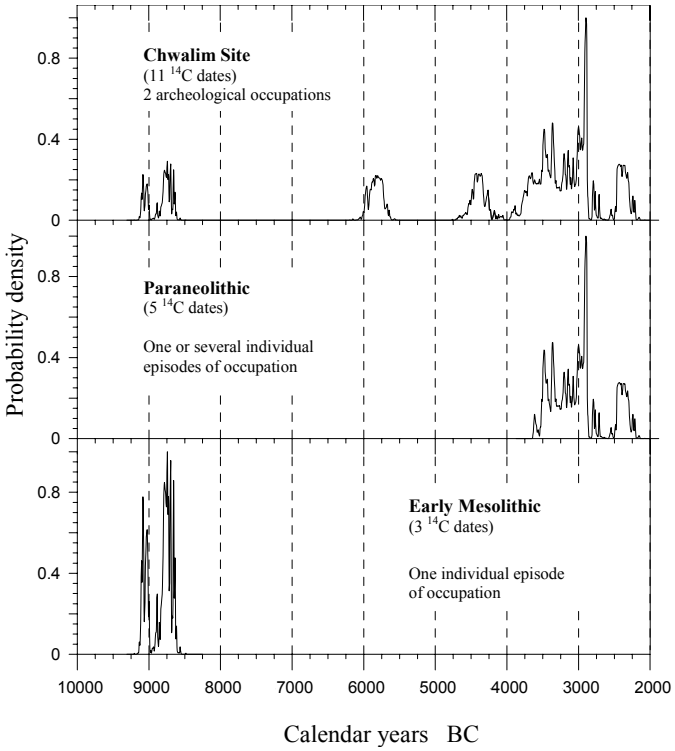

Figure 4 Cumulative probability density distributions of calibrated ^{14}C ages with the division into archaeological cultures from the Chwalim site.

In the case of the Całowanie site, this division was also assisted by the notable stratigraphy found in examined sections. This site has 11 culture levels associated with specific stratigraphic levels. Only 10 from 32 ^{14}C dates fit into the archaeological level from which they were selected (level I: CAMS 20868; level III: Gd-4165, Gd-5967; level IVa: Gd-2882, GrN-5410; level V: Gd-2723; level VIa: GrN-5409; level VII: GrN-5251, GrN-5442; level VIII: GrN-5966) (Table 3). The remaining 22 ^{14}C dates do not fit into the cultural levels precisely and the majority of them fit into several cultural levels simultaneously. The levels without ^{14}C dates are II, IVb, VIb, and VIc. The set of ^{14}C results and associated cultural levels are presented in Table 3.

Additionally, Figure 6 illustrates the cumulative probability density distributions of calibrated ^{14}C ages with the division into Glanów site 3 aggregations. The aggregations were established on the basis of the Mesolithic flint tools. These tools were grouped into 4 clusters (NE, E, NW, S) and each group was archaeologically identified as different (Figure 6a). Only flint tools and charcoals with ^{14}C ages older than 8000 BP were in agreement with archaeological stylistic determinations. Due to the possibility of stratigraphic problems within later levels of Glanów site 3, the aggregations are investigated for the Early Mesolithic only. The resultant distribution indicates the changes in settlement in the Early Mesolithic on Glanów site 3 terrain (Figure 6b, Table 1). The figure shows the probability density distributions of calibrated ^{14}C ages obtained on the basis of the ^{14}C calibration process. For the NE aggregation, 2 dates were calibrated, Gd-30016 and Gd-13003 (see also Table 1); for the E aggregation, 4 dates were calibrated, Gd-18161, Gd-17149, Gd-11413, and Gd-18160; the NW aggregation had 2 dates calibrated, Gd-17140 and Gd-10831; while the S aggregation also had 2 calibrated dates, Gd-10749 and Gd-12413. The comparison of the probability density distri-

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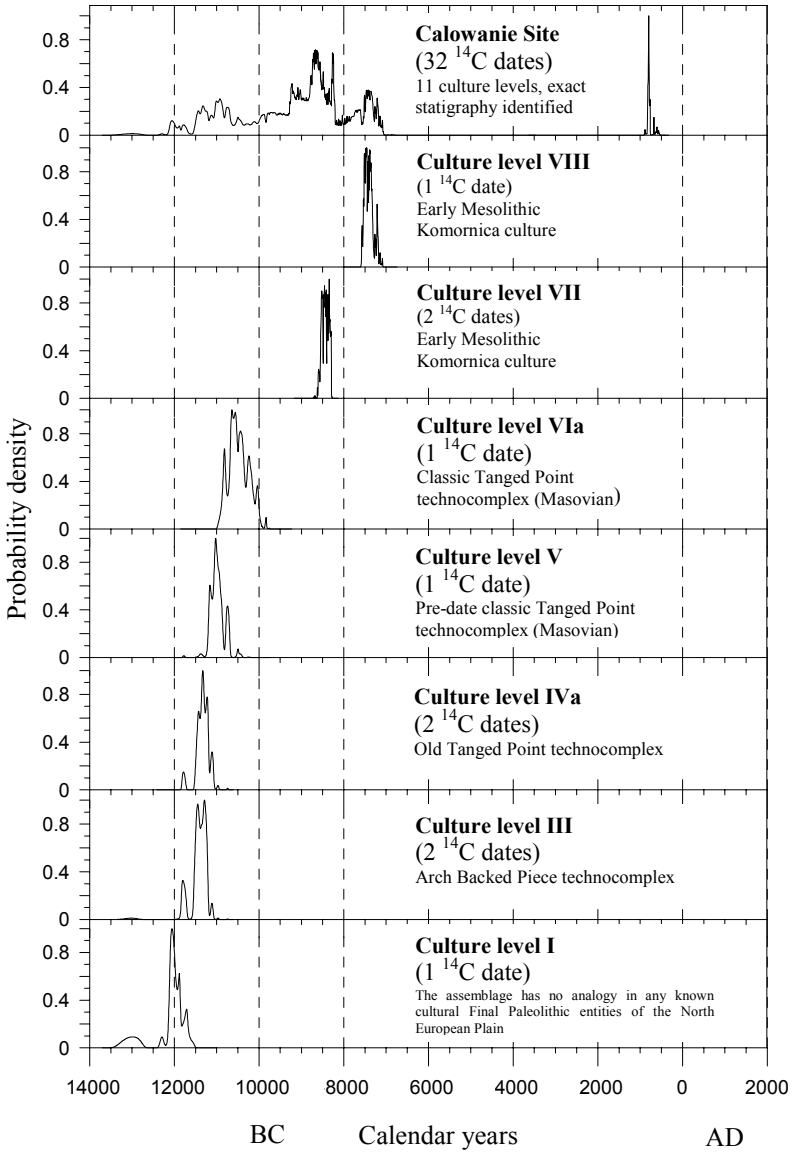

Figure 5 Cumulative probability density distribution of calibrated ^{14}C ages with the division into archaeological cultures from Całowanie Site.

butions of calibrated ^{14}C ages for all 4 aggregations illustrates the changes of settlement on Glanów site 3 terrain. In the age range of about 7940–7550 BC (Figure 6b), settlement activity took place on the NE, E, and NW. On the south part of Glanów site 3 for a similar age range, settlement activity did not occur. Similarly, in the period of about 7450–7050 BC (Figure 6b), human activity on the NE, E, and S aggregations was observed, while the NW aggregation in that age range did not practice husbandry. We also found the probability density distribution of calibrated ^{14}C ages for the NE aggregation shows the continuous settlement activity in all the age range of about 9500–6000 BC (Figure 6b), rising at the beginning and decreasing at the end of that period.

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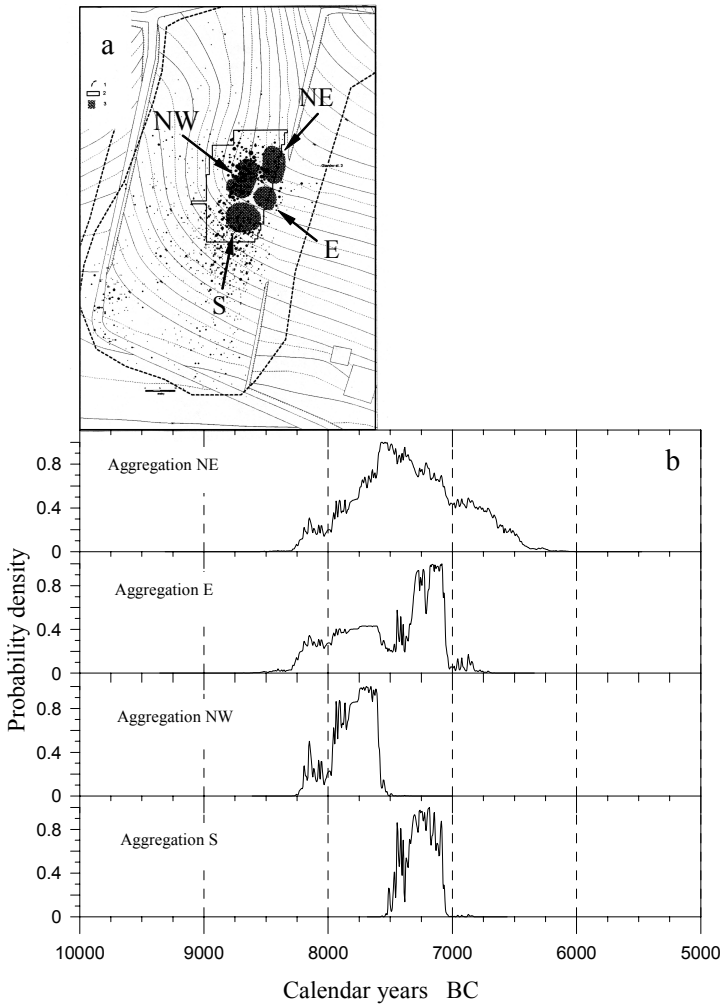

Figure 6 (a) Map of Glanów site 3 with the division into aggregations. The visible aggregations were identified into the Early Mesolithic on the basis of flint tools; (b) Probability distributions of calibrated ^{14}C ages from Glanów Site 3 aggregations. The cumulative probability density distributions show changes of settlement in the Early Mesolithic on this terrain.

SETTLEMENT PERIODS ON THE CLIMATIC BACKGROUND

In order to carry out analysis of climatic conditions, cumulative probability density distributions of calibrated ^{14}C ages from speleothems and peat formations from Poland were calculated. Results of the calculations are shown in Figure 7. The cumulative probability density distribution of calibrated ^{14}C ages from speleothems was done on the basis of 61 ^{14}C dates which belong in the time period ranging from 14,000 BC to AD 1. These dates were obtained from samples that come from caves in the south of Poland, Kraków–Wieluń Upland, where Glanów is situated (Pazdur et al. 1994, 1995).

Prior to calibration using OxCal v3.8, all ^{14}C dates from speleothems were corrected for a reservoir effect of 1350 yr (Pazdur et al. 1994, 1995). The comparison between cumulative probability density distributions of calibrated ^{14}C ages of speleothems and calibrated dates from Glanów site 3 shows

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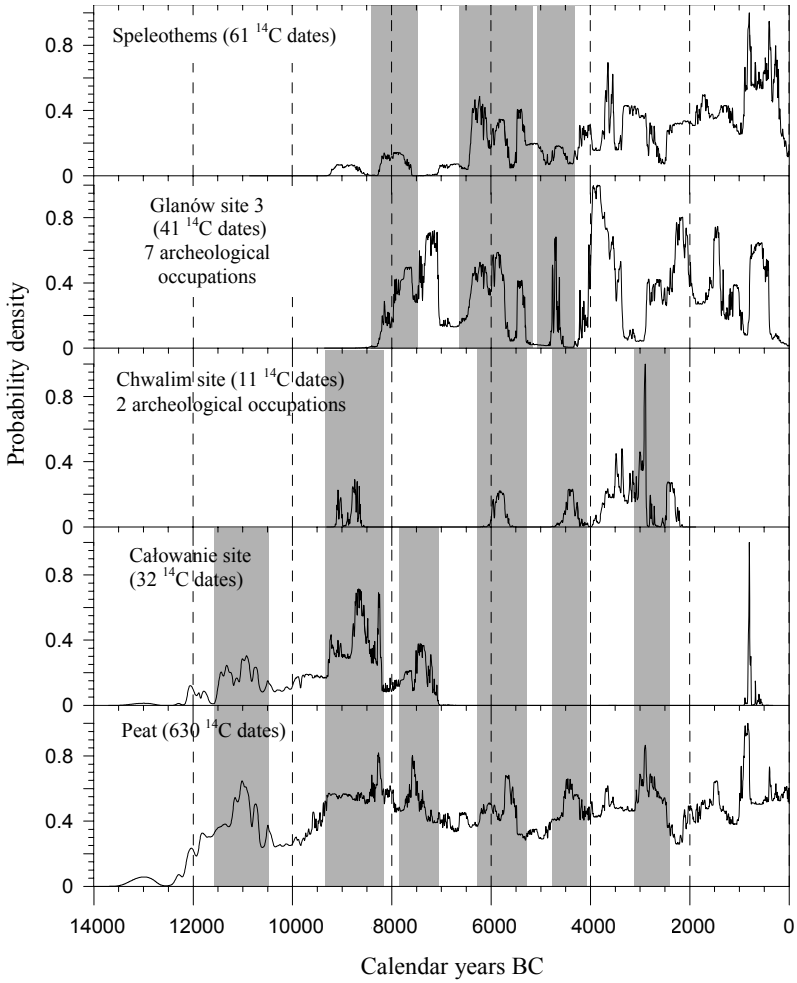

Figure 7 Comparison of probability distributions of calibrated ^{14}C ages from the Mesolithic sites in Glanów 3, Chwalim, and Całowanie. Additionally, the cumulative probability density distribution of calibrated ^{14}C ages from speleothems and peat from Poland are shown respectively on the top and bottom of the figure. These 2 cumulative probability density distributions illustrate the changes in climatic conditions. The grey fields indicate the coincidence between improving climatic conditions and an increase of human activities.

coincidence in the maxima at several Mesolithic time periods (Boreal period, about 8570–7530 BC [Figure 7]; at the beginning of the Atlantic period, about 7000–6500 BC; and in the Atlantic period at 6500–6100 BC, 6100–5500 BC, and 5500–5300 BC). Improving climatic conditions (maxima in the speleothems distributions; Figure 7) coincide with an increase of human activities in Glanów site 3. The increase in human activities creates a greater number of archaeological objects which allow a greater number of samples for each site and a higher number of dates for the sites to be obtained. A similar convergence of improving climatic conditions and an increase in human activities can be shown for the Chwalim and Całowanie sites (Figure 7). At the Całowanie and Chwalim sites, favorable conditions for the formation of peat are used as an indicator of mild climatic conditions. The 630 ^{14}C dates for statistical analysis were taken from peat sites distributed across Poland, with the exception of the Baltic coast (Michczyńska and Pazdur, unpublished data). The cumulative probability

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density distribution of calibrated ^{14}C dates from peat indicates periods of humid/dry climatic conditions (Figure 7). Maxima on the distribution are related to the humid climatic conditions and the highest human activity in the site at Całowanie and Chwalim (about 9000–8000 BC, 6000–5500 BC, 4750–4000 BC, 3000–2250 BC for the Chwalim site, and about 11,500–10,500 BC, 9250–8250 BC, 7750–7250 BC for the Całowanie site; Figure 7), while minima (the dry climatic conditions; Figure 7) coincide with lower human activity.

CONCLUSIONS

This study reviewed the results of ^{14}C dating from 3 Mesolithic sites in Poland and the cumulative probability density distributions of calibrated ^{14}C ages. Archaeological cultural determinations and site stratigraphy (where appropriate) were used to fit the time ranges into appropriate cultural associations. Additionally, correlation between formation of speleothems and peat as indicators of the climatic conditions and the development of human settlements was investigated. Comparison of the cumulative probability density distributions of settlements with cumulative probability density distributions from speleothems and peat bogs shows systematic relations between these distributions and the correlation between the initiation and growth of settlements and climatic conditions.

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