GEOCHRONOMETRIA Vol. 21, pp 129-136, 2002 – *Journal on Methods and Applications of Absolute Chronology*

RADIOCARBON DATED WOOD DEBRIS IN FLOODPLAIN DEPOSITS OF THE SAN RIVER IN THE BIESZCZADY MOUNTAINS

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Key words: WOOD DEBRIS, ALLUVIUM, RADIOCARBON DATING, HOLOCENE, CARPATHIANS

Abstract: Tree logs and smaller fragments of wood debris occur in floodplain alluvium (1-3 m above the river level) of the San river in the Bieszczady Mountains (Polish East Carpathians). The greatest accumulations of wood debris occur in the lower part of the alluvium, beneath a layer of sandy muds. The wood debris in these accumulations was dated by radiocarbon method. The dates fall within the time interval 3270±70 BP to 103.7±1.1 pMC, but most of them are from 17th to 19th century. The abundance of the wood debris in the alluvium is the result of its intense supply to the river channel, caused by deforestation and large floods. The age of the wood accumulations corresponds to the phase of settlement in the upper San valley in the 16th to 17th centuries. The older wood debris could be redeposited to the young alluvium from older alluvial terraces.

1. INTRODUCTION

Wood debris is usually a subordinate component in alluvial sediments and it usually widely varies in size. Large buried logs and other coarse wood fragments (branches, roots) usually focus the attention of researchers. Less visible is fine debris (leaves, bark, fruits and seeds) and this is usually omitted in descriptions of alluvial sediments. Dating of wood debris of all size provides an important insight into the age of alluvium and the evolution of river terraces. The most common methods used to date wood debris are radiocarbon (^{14}C) dating and dendrochronology.

Wood debris in alluvium of the Carpathian rivers occurs mainly in depositional covers of Holocene terraces. These are better preserved in foothill sections of valleys, not so common in the mountain zone. They are most common immediately below the outlets of the valleys from the Carpathians, e.g. in the valleys of the Wisłoka, Wisłok and San rivers (Starkel, 1960 and 1996; Klimek, 1974; Kalicki and Krąpiec, 1991; Krąpiec, 1992; Kalicki, 1997; Nogaj-Chachaj *et al.*, 1999). Their presence is commonly considered as indication of climate fluctuations and occurrence of floods in the Carpathians or lateral migration of fluvial channels (Środoń, 1952; Alexandrowicz *et al.*, 1981; Starkel, 1996 and 1999; Kalicki and Krąpiec 1991; Kalicki, 1991).

Geological studies in the Bieszczady Wysokie Mountains (Polish East Carpathians) have revealed the presence of abundant wood debris also in the mountane section of the San river (Haczewski *et al.,* 1998 and 2001). This is accumulated only in floodplain sediments of the San river and its tributaries, far upstream from the margin of the Carpathians. They form a continuous horizon in floodplain sediments, on the top of older gravels and at the base of the younger sandy mud (Kukulak, 2000). The accumulation of this wood debris seems to be not exclusively caused by a climatic factor.

This paper presents a description of wood debris in Upper San river floodplain alluvium and presents the results of its dating by the ^{14}C method. An attempt at explaining the causes of rich supply of wood debris to the river channel is also presented. The dated wood was collected from its rich accumulations in the alluvium in the headwater section (about 20 km long) of the San river, between its source at the Uzhok Pass (863 m a.s.l.) and the junction with the Muczny Stream (upstream from the Kiczera Dydiowska).

2. CHARACTERISTICS OF THE STUDY AREA

This part of the San river watershed has mountane relief near the water divide (long and steep slopes of the Pasmo Połonin Range) and foothill relief in the valley part (low altitude differences and gentle gradients). Most of the watershed is wooded (*ca*. 85%), only the highest parts of the Pasmo Połonin Range and the bottom of the San river valley (especially the Dźwiniacz Depression) are not forested. The dominant species of trees are beech (*ca* 46% in the Tarnawa forestry area), less abundant are spruce (*ca* 27%) and fir (*ca* 20%; Krygowski, 1975). The high percentage of forests in the slope areas retards the surface runoff from the abundant precipitation (*ca* 1100 mm per year) and reduces flood waves in the streams. The sediment load in the streams is now small during high water

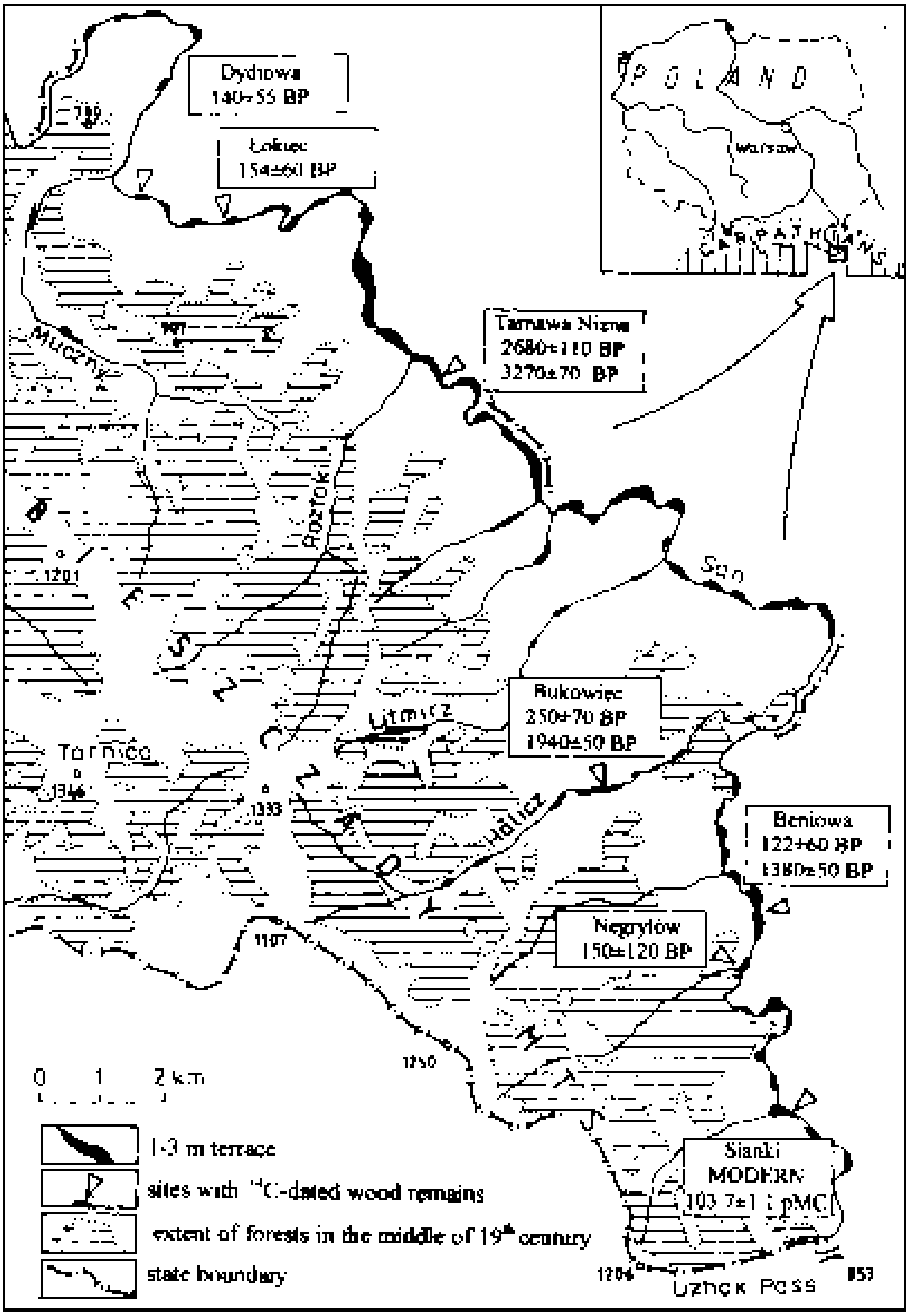

Fig. 1. *Extent of the lower fluvial terrace along the San river and its tributaries.*

states, as intense farming has ceased in the Polish part of the San river watershed (*ca* 80% of the total) half a century ago.

The floodplain is the lowermost level of alluvial deposition in a valley, older terraces lie higher and are arranged in steps. The height of the floodplain above the river level gradually increases downstream, from 0.5 m to 2 m, locally even to 3 m. At places it consists of two horizons (1.5-3 m, 0.5-1.5 m). The width of the terrace is greatest (50 m) in the Dźwiniacz Depression, where the vertical gradient of the river is lower than 0.5 % and the channel is meandering. The floodplain extends along the San river from its very source, and penetrates into valleys of bigger tributaries (Niedźwiedź, Sychłowaty, Halicz, Litmirz and Muczny streams). The sedimentary cover of the terrace differs from the older covers in its finer-grained sediments and a large content of wood debris. Fossil wood is only sporadically found in the sediments of the older terraces. The main horizon with wood debris has a constant stratigraphic position in the floodplain sections. It extends in the lower part of the alluvial cover, at the boundary between the lower gravels and the overlying sandy muds. The wood debris lies in layers or lenses of a few centimetres to 0.5 m thick. Meso-scale fragments of wood debris usually form one thick layer; the finer debris lies in two to five thin, laterally extensive layers. The higher, fine-grained part of the alluvial cover contains much less and finer wood debris. Only locally it fills erosional channels at different levels in the vertical sections or is dispersed in mineral deposits.

3. MATERIAL AND METHODS

Accumulation of plant debris in exposures of floodplain deposits have been studied and documented in years 1996-2000. Determined were forms of the accumulations, their state of preservation; the remains have been identified in selected sections of the terrace (Haczewski *et al.*, 1998). Wood from several debris accumulations was collected for radiocarbon dating (Sianki, Beniowa, Bukowiec, Tarnawa Niżna, Łokieć and Dydiowa). One or two samples were taken from each of the selected accumulations, all from the lower part of the vertical sequence (boundary between gravel and sandy mud).

All datings were done in years 1997-2000; most of them in the Gliwice (A. Pazdur), a part in the Cracow Radiocarbon Laboratories (T. Kuc). ^{14}C concentration in the samples was measured in the Gliwice Radiocarbon Laboratory by gas proportional counting and in the Cracow Radiocarbon Laboratory by liquid scintillation counting. $\delta^{13}C$ was determined in mass spectrometer, thus conventional radiocarbon age was normalised to $\delta^{13}C = -25‰$, according to the Stuiver and Polach's procedure (1977). ^{14}C dates were calibrated by use of the Gliwice calibration Program GdCALIB (Pazdur and Michczyńska, 1989), except for some dates of radiocarbon age less than 300 BP, which were calibrated by OxCAL (Ramsey, 1995). In both cases the calibration curve of Stuiver *et al.* (1998) was used. **Table 1** shows the results of radiocarbon dating as conventional radiocarbon ages (^{14}C Age, BP) and after calibration procedure, as the intervals of the highest probability at confidence level 68% (Cal. Age, AD/BC).

Geological, archaeological and historical data have been compiled for the period indicated by the radiocarbon dates, including results of palaeobotanical analyses of local peat-bogs (Pałczyński, 1962; Marek and Pałczyński 1962; Zarzycki, 1963; Ralska-Jasiewiczowa, 1969, 1980 and 1989). These mainly record changes in a vegetation cover of the Bieszczady Mountains during the Holocene, thus indirectly they reflect the phase of a climatic change and early human activity. Archaeological findings are few in the studied area and they suggest rather migrations than settlement in pre-historic times (Reyman, 1958; Parczewski, 1991). Historical data on the San river valley have been collected from archival maps, cadasters, chronicles and published studies (Kummerer, 1855; Akta, 1868; Stadnicki, 1848; Fastnacht, 1962). History of forests and their management during the last five centuries are well documented in the above sources.

4. RESULTS

Meso-scale components of fossil wood in the floodplain sediments are logs and their fragments, branches, roots and sporadic polypores. The accumulation of fine debris consist mainly of leaves, bark, fruits and seeds. Noteworthy is the large proportion of bark, branches and tree tops. The wood debris is accompanied by fragments of peat, herbaceous plants and their fruits and seeds, fungal sclerotia and insect remains. Microscope studies of the fine alluvium reveal a significant admixture of microscopic plant detritus in all size fractions. Coarse logs are usually found in shallow erosional troughs dissecting gravels (Beniowa) or in channel sediments at palaeochannel bends (Tarnawa Niżna). They are buried in sand and fine gravel, some logs are completely buried in gravel (Bukowiec and Tarnawa Niżna). The finer wood debris occurs only in the sandy mud, in sections of flat ancient river bottom.

Most logs are well preserved. They lack large fragments of bark, but all have cambium preserved. Stumps complete with roots and branches are rare. Locally rotten logs with still visible internal structure also occur. A few logs at Beniowa and Bukowiec bear traces of working with tools (wedge-shaped axe-made incisions and saw-made cuts). A wooden board, symmetrically cut on both sides and perforated, apparently a household object, is exposed at the bottom of the mud layer at Sianki. Many finer wood fragments at Sianki and Tarnawa Niżna are partly impregnated or coated with iron oxides, which makes them more resistant to decay. Some of the wood fragments are charred or scorched (Kukulak, 2000).

Each of the wood debris accumulations is a separate assemblage of size classes, usually composed of several similar classes. The accumulations of coarse wood debris usually lack finer detritus or have only a small proportion of it. The areally more extensive wood debris accumulations display a lateral trend in grain size, depending on the form of accumulation. Besides size sorting (layers of leaves or branches), weight sorting also occurs (e.g. fruits, bark). These features are better visible in the accumulations of plant detritus in low-gradient segments of the valleys (Beniowa and Łokieć). Wood in each of the eight radiocarbon-dated samples, has a different conventional radiocarbon age (**Table 1**). The obtained dates cover a wide time interval: from 3270±70 BP (Tarnawa Niżna I) to modern - 103.7±1.1 pMC (Sianki). Half of the dated samples represent wood that died at modern times (18^{th}-19^{th} centuries). The dates of wood from Beniowa (122±60 BP), wattle made from thin stems and twigs at Łokieć (150 ±60 BP) and a layer of beech leaves at Dydiowa (140±60 BP) fall within a very narrow time interval. The other half of the samples consisted of much older wood, and the differences in their ages attain 500-700 years. Only at Tarnawa Niżna, wood from a thick log (I) and fir cones (II) buried in the same horizon, have similar ages (terminal part of the Subboreal Epoch of the Holocene).

Dating of the studied wood debris indicate that wood debris of various age has been buried in the floodplain alluvium. Very young is the debris that fills an erosional channel at Sianki, older are artificial wattle reinforcements at Łokieć. The logs buried in the basal gravels at Bukowiec are from the beginning of the Common Era, and those at Tarnawa Niżna are as old as Subboreal. The presence and predominance in the alluvium of wood debris dated at the last three centuries, proves that most of the debris was accumulated at times close to, or only slightly later than, its radiocarbon dates. It could occur in the 18^{th} or 19^{th} century. The dates of these samples do not determine the age of the main wood debris horizon over the whole length of the San valley. Also the presence of the oldest wood in this horizon (Tarnawa Niżna) may be the result of its redeposition from older terraces.

5. DISCUSSION AND CONCLUSIONS

The times of plant death indicated by the radiocarbon dates of wood are related to events of both climatic (the older dates) and anthropogenic (the younger dates) nature in the natural environment of the Bieszczady Mountains. The age of the buried logs at Tarnawa Niżna corresponds to the phase of frequent floods in the watershed of the upper Vistula River towards the end of the Subboreal time (Starkel, 1977 and 1994). Also the age of the logs at Bukowiec is isochronous with floods in the Carpathian rivers in Roman times, and the fragments from Beniowa – with floods in early Mediaeval times (**Fig. 2**). The flood sediments of the upper Vistula river laid down at those periods include numerous buried logs (Awsiuk *et al.*, 1980; Kalicki and Krąpiec, 1991 and 1996; Krąpiec, 1992). The older dates from the studied wood debris fit well within the phases of the San river floods and may be related to climatic conditions. The number of older dates is, however, too small to exclude that the coincidence is only accidental.

The accumulations of the younger wood debris have been also laid down during floods, but the cause of their deposition seems to be mainly anthropogenic. It is related to the phase of settlement and onset of farming in the part of the Bieszczady Mountains during late Mediaeval and early Modern times. Many permanent settlements of farmers and wood workers have been founded here on inhabited grounds during the second half of the 16^{th} and at the beginning of 17^{th} century. These have evolved later into agricultural villages (Fastnacht, 1962). The settlements were located in areas that were already partly deforested as pasture grounds at valley bottoms (Ternowe

Table 1. *Description (name, depth, material) and conventional and calibrated ages of the samples. Calibrated age range has been determined with confidence level 68% using the GdCALIB programme, developed in the Gliwice Radiocarbon Laboratory and Oxford programme OxCal for very young samples.*

Sample name/depth **Dating material**	**Lab. No.**	**^{14}C Age** [BP]	**Range of Cal. Age** [AD/BC]
Sianki/0.95-1.05 m Twigs, cones	Gd-15166	103.7±1.1pMC (*)	MODERN
Beniowa I/0.7 m Charcoal	KR-168	122±60	[1800, 1950] AD
Beniowa II/1.45-1.55 m Leafs, twigs, bark	Gd-11555	1380±50	[636, 686] AD
Bukowiec/2.6-2.8 m Wood	Gd-7860	1940±50	[21, 91] AD
Tarnawa Niżna I/1.1-1.2 m Wood	Gd-12136	3270±70	[1621, 1491] BC
Tarnawa Niżna II/1.60-1.65 m Twigs, cones	Gd- 15194	2680±70	[1002, 762] BC
Łokieć/2.5 m Wood	KR-167	150±60	[1720, 1820] AD
Dydiowa/0.7 m Leaves, twigs	KR-172	140±60	[1800, 1890] AD

Cal. Age = calibrated age, Lab. No.= laboratory number, Gd- = Lab. No. of ^{14}C dates from Gliwice Radiocarbon Laboratory, KR- = Lab. No. of ^{14}C dates from Laboratory of the University of Mining and Metallurgy, Cracow , (*) = pMC-percent of modern carbon.

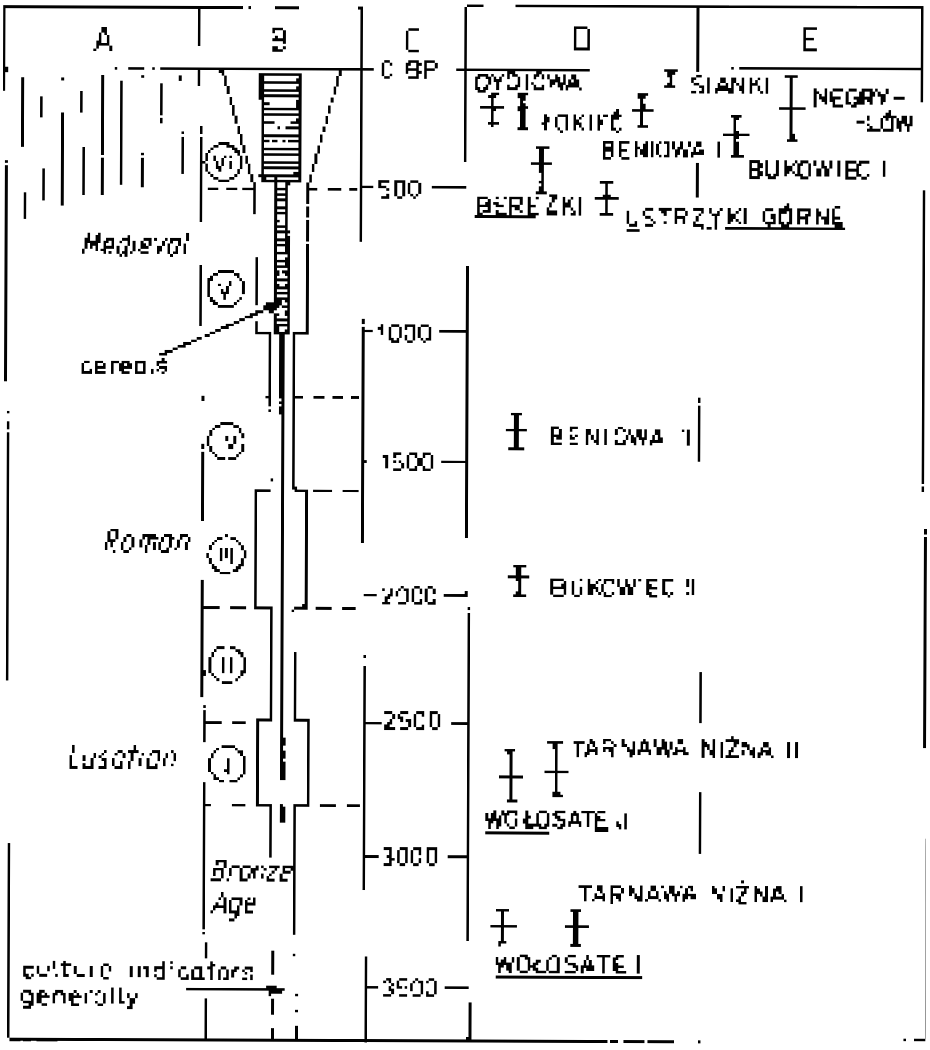

Fig. 2. Corelation of phases of settlement in the Bieszczady Mountains with the age of wood debris in the lowest (1-3 m) terrace. A – period of permanent settlement and farming in the Bieszczady Mountains; B – record of human influence on environment in pollen diagrams of peat-bogs (after Ralska-Jasiewiczowa, 1989); C – radiocarbon dates; D – dated wood fragments at the bottom of the fine-grained; E – dated wood fragments from the fillings of erosional thoughs in the alluvial terrace. Archaeologic periods: I – Hallstatt, II - La Tène, III – Roman, IV – Migration, V – Medieval, VI – Modern times. Underlined are dates from San tributary situated off the west margin of ***Fig. 1****.*

Pole, Beniowe Pole and Pole Bukowiec). The glades were mainly the work of the Valachian herders who were coming here seasonally from the 14th to 16th century, with their herds of cattle and sheep (Kubijowicz, 1926; Parczewski, 1991).

The first villages were located in the Dźwiniacz Depression: Dźwiniacz Górny (before 1529), Tarnawa Niżna and Tarnawa Wyżna (1537). The expansion of settlements reached the Uzhok Pass in the end of the 16th century: Bukowiec (1580), Beniowa (1580) and Sianki (1580). The economy of these villages was based on cattle herding and grain growing, activities that required wide expansion of farmland. Clear cutting of forests began on great scale, providing areas for arable fields and meadows. The clearcuts were not limited to the areas around villages but also included widening of natural mountain meadows on the mountain crests (so called poloninas). Tax registers from the 16th and 17th centuries (Spisy, 1787), land cadasters from the 18th. (Akta, 1868) and old maps from the 18th-19th centuries (Liesganig, 1824; Kummerer, 1855) prove a nearly complete deforestation of the valley bottom, a large reduction in the forest area on slopes and lowered timberline around the poloninas.

The clearing of forest was done mainly by fire clearance. Initially, this was the easiest way to gain farmland, then also to fertilise it (Kubijowicz, 1926; Broda, 1952; Pałczyński, 1962). The settlers usually did not perform complete clearcutting and did not clear the area of branches, tree tops and bark. This wood debris was burnt in place or thrown away to stream channels (Szwab, 1956). The rapid re-growing of woods in non-cultivated ground and repeated cutting in the same places favoured accumulation of large amounts of wood debris in nearby stream channels. The initial phase of settlement in the San river valley had to be the most productive in wood litter.

The increased runoff due to deforestation of slopes resulted in more violent flooding of the streams and enabled transport of the wood debris to the San river channel. This supply had to be rich, as the debris formed thick accumulations in the channel sediments and erosional troughs on terraces. The deposition of wood debris was accompanied by increased load of slope-derived sediments in flood waters. This increased supply of clay from arable fields resulted in a tendency to alluvial aggradation in the San river channel. The alluvial aggradation was the fastest along reaches with low vertical gradient (below 0.5%). It was also at those places where the greatest amount of wood debris was laid down. The burnt and charred wood found in this debris may be the product of fire clearance. The radiocarbon dates from the burnt wood at Beniowa correspond to the period of the greatest activity of local wood-burning industries (potash-making facilities, blacksmithery and steam-powered sawmills). A large part of the buried logs may have come from undercutting of river banks, as conditions for lateral channel migration existed during the greater floods.

All the wood debris, dated at various periods of the late Holocene, is now buried in the alluvial cover of the same terrace. The interpretation of time of their deposition in the alluvium is thus not unequivocal. One may assume that the floodplain consists of fragments of different age, so that older wood is buried in the older fragments, and younger wood in the younger ones. The division of the terrace into fragments of different age is, however, expressed in its stratification (gravels at bottom, mud above) rather than in the presence of laterally adjacent segments of different age (due to lateral aggradation). Only a part of the fine-grained alluvium (the upper part of the cover) includes fills of linear erosional troughs. The main horizon of wood debris forms a layer in the terrace and it seems to be isochronous. It is thus more likely that the older wood debris was redeposited to the young alluvium from the older terraces of the San.

6. ACKNOWLEDGEMENTS

The paper is based on data obtained during geological mapping in the Bieszczady Mountains. The mapping project was led by Professor Grzegorz Haczewski who provided assistance in the fieldwork, in the discusion of the results and translated the text to English. Professor Michał Parczewski of Jagiellonian University has introduced J.Kukulak into the recent results of archaeological research in the Bieszczady.

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