STUDIA GEOMORPHOLOGICA CARPATHO-BALCANICA
VOL. XXXVII KRAKÓW 2003 PL ISSN 0081-6434
LANDFORM EVOLUTION IN MOUNTAIN AREAS

WŁODZIMIERZ MARGIELEWSKI (KRAKÓW), NIKOLAI KOVALYUKH (KIEV)

NEOHOLOCENE CLIMATIC CHANGES RECORDED IN LANDSLIDE'S PEAT BOG ON MOUNT ĆWILIN (BESKID WYSPOWY RANGE, OUTER CARPATHIANS, SOUTH POLAND)

Abstract. Three peat bogs with minerogenic levels inside peat had been distinguished within the landslide formed on the western slope of Mount Ćwilin (Beskid Wyspowy Range, Polish Outer Carpathians). The central peat bog dated at the beginning of the Subatlantic phase 2,420 ±80 years BP (790–380 cal BC) is filled with thick 3.8 m wood and sedge-moss peat. Within this peat bog several minerogenic levels (sand, sandy silt, silty clay, clayey silt) connected with activation of alluvial fan. Time formation of these levels was defined by 25 radiocarbon datings. The datings show that high-energy sediments were deposited at ca: 370–40 cal BC, 530–1,050 cal AD and 1,150–1,440 cal AD, when growth of humidity of the climate were recorded. Register of these events well correlates with phases of fluvial activity of the Upper Vistula river as well as with phases of mass movements intensification in the European mountains. During the phase of humidity growth 1,150–1,440 cal AD the next peat bog in the Ćwilin set (southern, 1.5 m thick) was also formed (it was dated at 850 ±70 years BP). Minerogenic sediments (clayey silt) 0.6 m thick dated at ca 1,410–1,640 cal AD cover the peat there. Therefore the sediments originated during humidity growth and cooling of the climate called Little Ice Age. The third peat bog (northern) in described set was formed at the beginning of Subatlantic phase and at the bottom of peat (0.9 m thick) high-energy deposits dated at 2,020 ±70 years BP (210 cal BC–140 cal AD) are present.

Key words: landslide's peat bog, climatic changes, Neoholocene, landslide phases, Outer Carpathians

INTRODUCTION

Sedimentary reservoirs occurring in the mountain areas are sensitive indicators of changes in palaeoenvironment. In sediments of high mountain lakes, levels of high-energy deposits connected with debris flows show the increase of frequency of hydrometeorologic extreme events characteristic of climate humidity growth in the Late Glacial and the Holocene (Jonasson 1993; Baumgart-Kotarba and Kotarba 1993, 1997; Kotarba 1995, 1996; Ballantyne 2002; Dapples et al. 2002). Peat bogs of fen type developed in landslide depres-

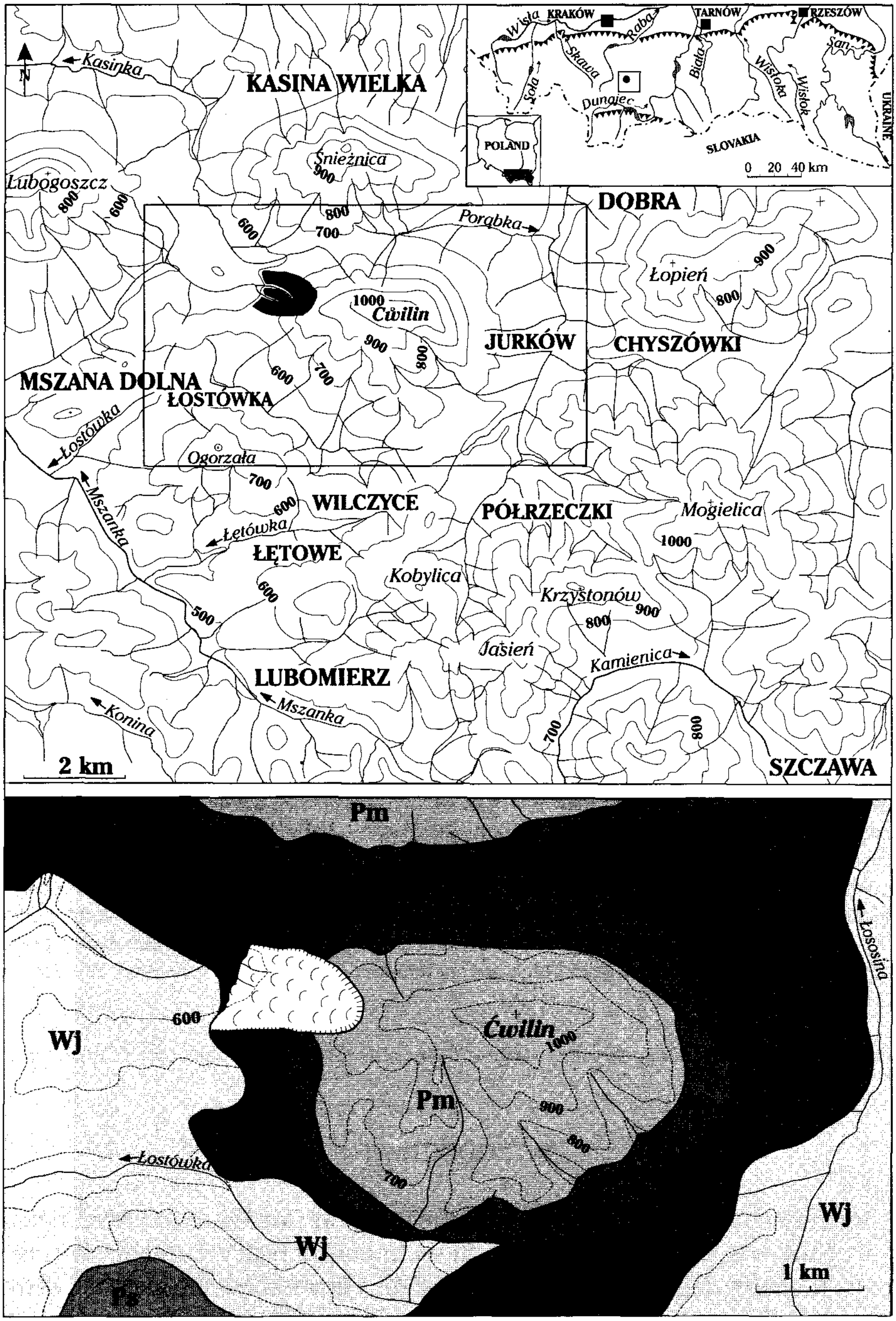

Fig. 1. Locality of the Ćwilin landslide with geological setting of the region. Geology after J. Burtan (1974). Pm — thick bedded Magura Sandstones, Wh — Hieroglyphic Beds (thin beded flysch), Lp — Variegated Shales, Wj — Jaworzyna Beds (thin bedded flysch), Ps — Szczawina Sandstones (thick bedded sandstones)

sions are another particular environment of sedimentation reacting to intensification of hydrometeorologic phenomena. A break in peat deposition and sedimentation of intercalations of minerogenic deposits followed as a result of rich supply of allochthonous material washed away from the colluvium to the peat bog during extreme hydrometeorologic events. Therefore minerogenic levels occurring in peat are distinct indicator of climate humidity growth. Dating of these levels allows to analyse climate changes in the Late Glacial and the Holocene (Gil et al. 1974; Reneau et al. 1990; Starkel 1995, 1997; Corsini et al. 2001; Margielewski 2001a, b, 2002; Szczepanek 2001; Dapples et al. 2002).

One of such landslides, where peat bogs with minerogenic levels occur, was stated on the western slopes of Mount Ćwilin in the Beskid Wyspowy Range (Outer Carpathians) (Fig. 1) (Starkel 1960; Margielewski and Kovalyukh 2001). Dating of minerogenic levels in peat allowed to reconstruct phases of the climate humidity growth during the Subatlantic.

GEOLOGICAL SETTING

The Mount Ćwilin occurs within the Siary Zone of the Magura Nappe (Burtan 1974). The top part of the Mount were formed within resistance, thick bedded Magura Sandstones, while lower part are in the Hierogliphic Beds (tin bedded flysch formation), which form the Ćwilin's brachysyncline (Burtan 1974). The above mentioned sediments are underlain mainly by variegated shales (Fig. 1).

Mount Ćwilin with neibouring Mount Śnieżnica creates the watershed (divide) between the Raba River and the Dunajec River. Western slopes of Mount Ćwilin (with analysed landslide) are drained by streams being tributaries of the Raba River (Fig. 1).

LANDSLIDE DESCRIPTION

The landslide formed on the western slope of Mount Ćwilin has amphitheatre shape of the main scarp (head scarp) over 80.0 m high well visible in landscape, developed in thick-bedded Magura Sandstone at 880–800 m a.s.l. (Fig. 1). Lower parts of the landslide formed as colluvial swells, steps and tongues and depressions occurring within the colluvium were developed in soft Hieroglyphic Beds and partly in variegated shales (Fig. 1) (Starkel 1960; Margielewski and Kovalukh 2001). The form represents the rotational type of a landslide (Dikau et al. 1996) subsequent in relation to the attitude of beds (Figs. 1, 2) (Ziętara 1969; Bober 1984).

Lower parts of the landslide were strongly transformed during the secondary movements. Number of secondary landslide forms with amphitheatre scarps and depressions at their foots contemporary filled with peat bog fens were formed at

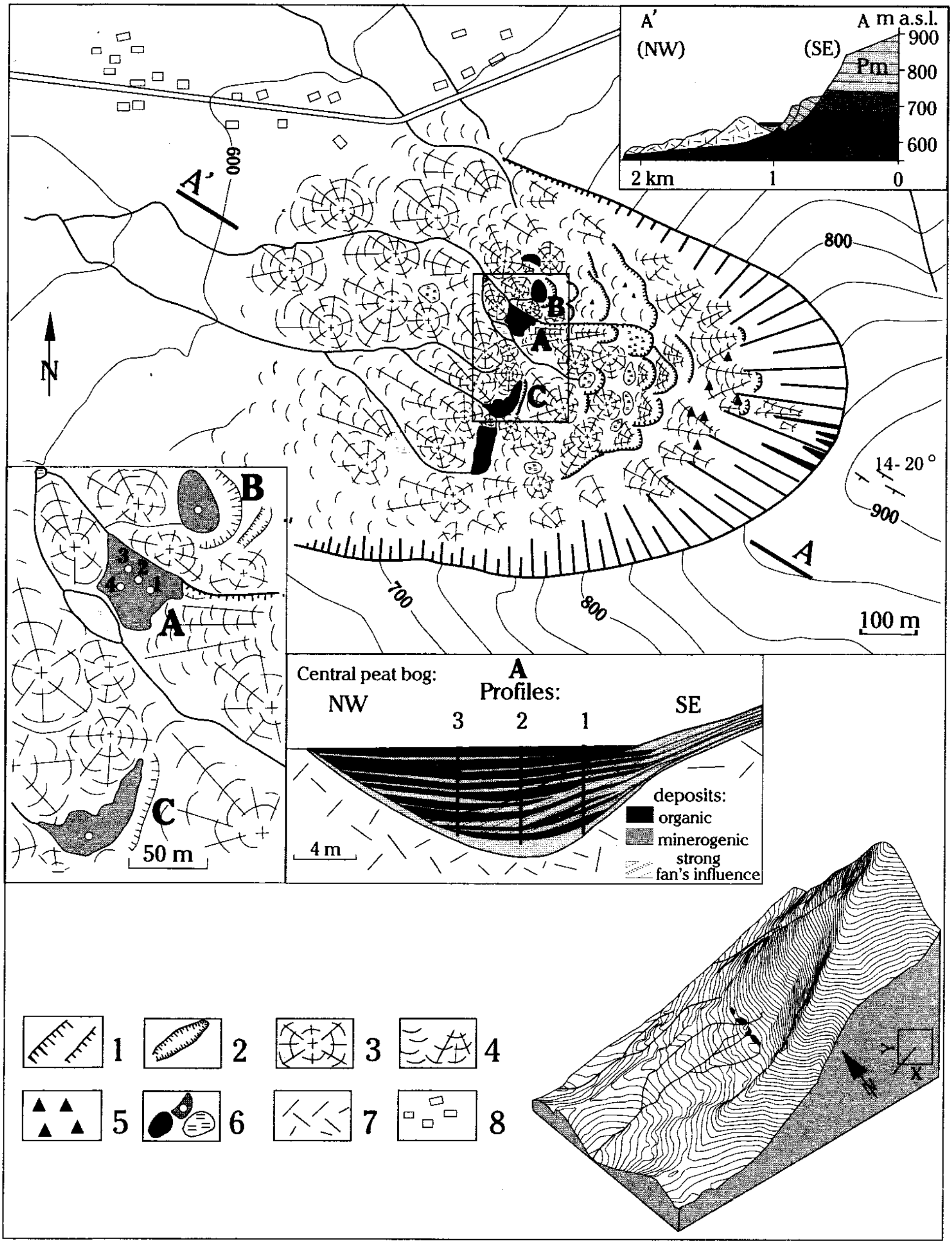

Fig. 2. Plan of the Ćwilin landslide, with the cross-section and orthogonal projections of hipsometry in Z value. A, B, C — peat bogs mentioned in the text, with the sampling place, and with the cross section along the central peat bog (A), 1 — main scarp and another scarp, 2 — trench, 3 — colluvial swell and colluvial tongue, 4 — creeping, 5 — sandstone tor, 6 — peat bog and swamp with the sampling place, 7 — mixed colluvial material (on the cross section), 8 — building. Other explanation — see Fig. 1

that time (Fig. 2). Three peat bogs were analysed. The deepest depression filled with a peat bog is in the central part of a landslide (Fig. 2 — depression A). The form is ca 60 m long, ca 40 m wide and its maximum depth in the middle parts reaches ca 3.8 m. From the west and the north the depression is blocked with colluvial ramparts. From the east, vast alluvial fan (150 m long and 40 m wide) is encroaching on the peat bog area (Fig. 2). Fan deposits formed several levels of minerogenic sediments and were supplied during climate humidity growth.

The second peat bog (northern peat bog) is northwards and fills the oval depression of 20 m in diameter and of ca 2 m depth. Depression is between amphitheatre scarp and colluvial swell (Fig. 2 — depression B).

The third peat bog (southern peat bog), fills the depression southwards of central peat bog (Fig. 2 — depression C). It has elongated, sickle-shaped form (60 m long, 30 m wide and 1.55 m deep). Moss fen peat covered with minerogenic deposits (ca 0.6 m thick) fills the depression.

MATERIALS AND METHODS

A Russian peat samplers (diameter: 5 and 8 cm) was used for sampling the sediments filling up the deppressions. 31 drillings were done in the peat bogs: 24 drillings were made in the central peat bog (Fig. 2 — A), 3 drillings in the northern peat bog (Fig. 2 — B) and 4 drillings in the southern peat bog (Fig. 2 — C). Organic deposits were performed by Dr K. Lipka from Agriculture Academy in Kraków, peat classification after S. Tołpa et al. 1967. Areometric analyses by Casagrande method (vide: i.e. Lityński et al. 1976) were done for minerogenic sediments and litholocal classification according to F. Shepard (1954). The percentage of organic matter was estimated by loss-on-ignition (LOI) at 550°C (Dean 1974), for the each 2.5 cm thick fragment of core (Fig. 3). The sedimentation changes were dated by ^{14}C (Table 1, Figs. 3, 4). All conventional (BP) radiocarbon analysis based on various material obtained from cores (see Table 1), were carried out at the Kiev Radiocarbon Laboratory (Ukraine). Calibrations of radiocarbon datings (expressed as cal yr BC/AD) were made using the calibration data set of M. Stuiver et al. (1998) (Table 1, Fig. 5). Pollen analyse for the one sample from bottom of central peat bog (confirmed of the radiocarbon dating) was made by Dr V. Zernitskaya from the Institute of Geological Sciences (Belarus Academy of Sciences, Mińsk) (Fig. 3).

DEPOSITS OF THE CENTRAL PEAT BOG

Deposits of the central peat bog (Fig. 2A) are characterised of significant variability. Several drillings showed alternate occurrence of organic and mineral deposits caused by periodical activity of alluvial fan delivering allochthonous material

(Fig. 3). Within this peat bog four profiles sampled for every 4 m were analysed in details (Fig. 3). Three of them — profiles 1–3 were sampled in SE–NW direction and fourth in south-western part (Figs. 2, 3). Sediments deposited closest to the fan, in the eastern part of the peat bog, show the highest content of minerogenic material and in the western direction steady supply of allochthonous sediments is visible mainly at the bottom parts of the profile and decrease together with the distance from the fan (Fig. 3).

Sediments start with bottom silt with fragments of sandstone stuffing up the depression which in profile 1 (closest to the fan, 7 m far removed) was distinguished as sandy silt (interval 3.8–3.2 m) (Fig. 3 — profile 1). In profile 2, within this stuffing up sediment, at the depth of ca 3.4 m the trunk buried in the sediments was drilled. The trunk was dated by radiocarbon method at 2,420 ±80 years BP (790–380 cal BC) (Fig. 3 — profile 2). The date was confirmed by palynological analysis of peat occurring over the stuffing up silt dated at 2,205 ±80 years BP (400–50 cal BC) (Fig. 3 — profile 2). Numerous pollens of *Abies alba* less numerous pollens of *Pinus* with marked participation of *Fagus, Tilia, Fraxinus, Carpinus* and *Corylus* were stated there. Association of pollens points out that deposition of peat started at the beginning of the Subatlantic phase and shows great significance of radiocarbon datings of bottom parts of the peat bog (Fig. 3; Table 1).

Above, on the bottom deposits strongly polluted (by sandy silt) woody osier peat occurs (*Alnioni saliceti* after Tołpa et al. 1967). In profile 1, they are in the depth interval 3.2–2.9 m and the end of their deposition was dated here at 2,180 ±80 years BP (400–40 cal BC) (Fig. 3 — profile 1). In the next profile drilled 4 m to the west (Fig. 3 — profile 2) an intercalation of similar peat was deposited after the date 2,205 ±80 years BP (400–50 cal BC) (Table 1). In the profile from the most external parts of the peat bog, the peat insert is poorly marked on L.O.I. curve (Fig. 3 — profile 3).

Over woody osier peat, a level of minerogenic deposits (sandy silt) occurs. In profile 1, it was dated at 2,180 ±80 years BP (this date states the end of woody osier peat deposition — see above) and in profile 2 (see — Fig. 3) the bottom of this level was dated at 2,100 ± 80 years BP (370 cal BC–60 cal AD). In profile 3, this level was dated at before 2,145 ±60 years BP (380–40 cal BC) (Fig. 3 — profile 3).

The layer of organic sediments occurs over the minerogenic level. In profile 1 (Fig. 3) in the depth interval 2.7–2.5 m strongly polluted woody birch peat (*Alnioni betuleti*). Above occurs sedge-moss fen peat (*Bryalo-parvocaricioni, Cariceto-bryaleti*) occurs which up to the surface is periodically substituted by minerogenic sediment. In its upper part characteristic peat-minerogenic interbeddings occur (in streaks of 1 cm thick sedge-moss fen peat and sandy silt occur by turns). The whole organic-mineral sequence present in profile 1 in the interval 2.4–2.2 m originated as a result of recurrent supplies of minerogenic sediments to the peat bog and is a group of events. The start of peat-mineral series deposition in profile 1 was dated at 1,470 ±60 years BP (430–670 cal AD).

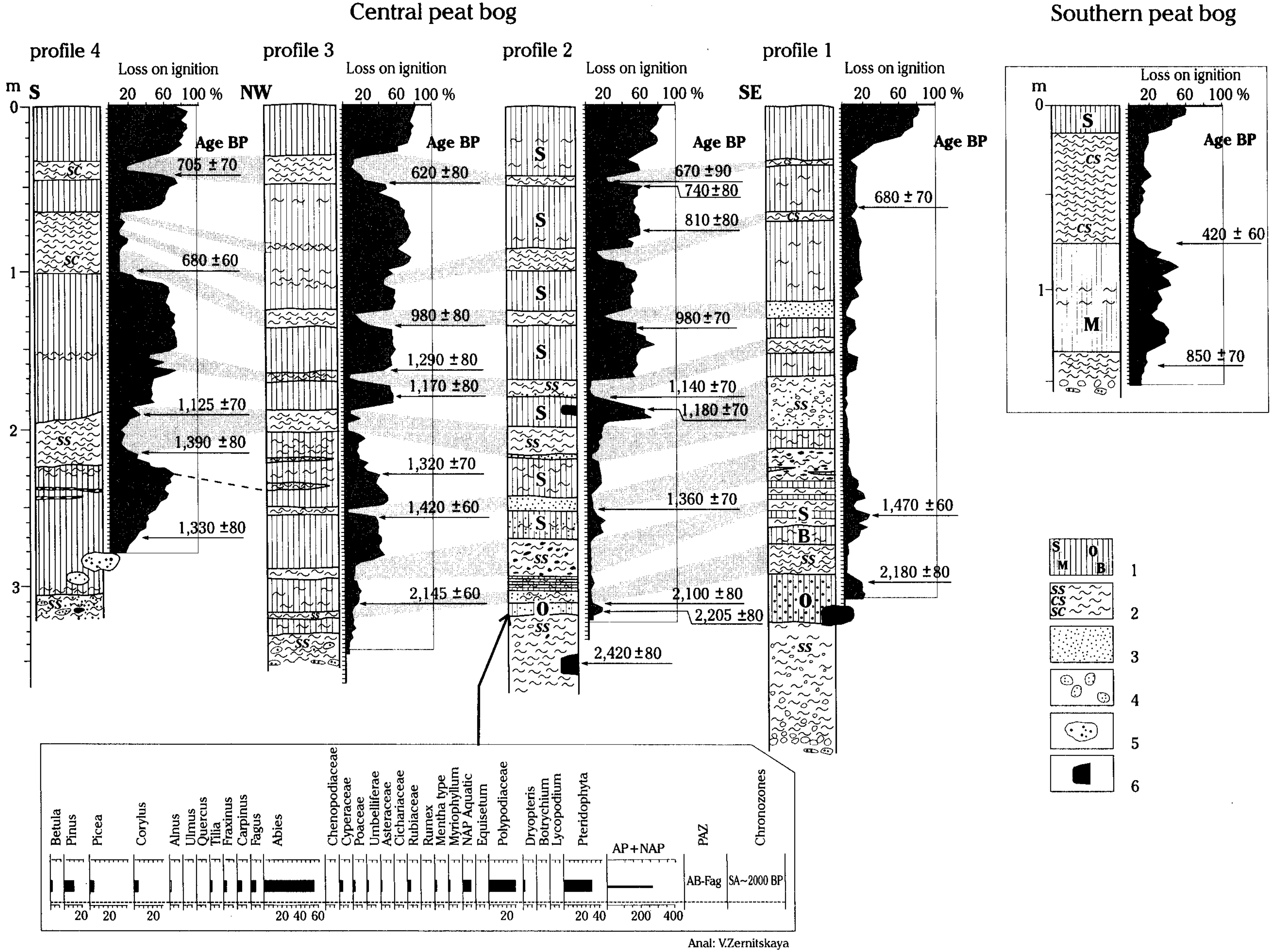

Fig. 3. The profiles of the central peat bog of the Ćwilin Landslide (profiles 1–4, see Fig. 2 — A), and the southern peat bog (see Fig. 2 — C), with the loss on ignition curves and the radiocarbon datings (BP). Sampling places — see Fig. 2. Below, the result of pollen analyse of one sample from the bottom of the central peat bog (analysed by V. Zernitskaya). 1 — peat: S — sedge moss fen peat, M — moss fen peat, O — woody osier peat, B — woody birch peat, 2 — minerogenic deposits: ss — sandy silt, cs — clayey silt, sc — silty clay, 3 — minerogenic deposits: sand and gravel, 4 — bottom debris, 5 — rock block, 6 — tree trunk

Table 1

Radiocarbon datings of the Ćwilin peat bog. Callibration after M. Stuiver et al. 1998

Depth [cm]	Material	Lab. Code	Age ^{14}C (yrs BP)	Calendar age 2σ (cal yr BC–AD)	Context of datings
Central peat bog (Figs. 2 — A, 3)					
Profile 1					
62–65	Charcoal	Ki-10515	680 ±70	1,220–1,410 cal AD	Minerogenic level sedimentation Anthropogenic deforestation
256–261	Bark	Ki-9585	1,470 ±60	430–670 cal AD	Start of minerogenic level sedim.
287–297	Wood fragments	Ki-9761	2,180 ±80	400–40 cal BC	Start of minerogenic level sedim.
Profile 2					
44–48	Silt with organic	Ki-8188	670 ±90	1,180–1,440 cal AD	Start of minerogenic level sediment.
46–50	Peat	Ki-8187	740 ±80	1,150–1,410 cal AD	Minerogenic level sedimentation
75–77	Wood fragments	Ki-9759	810 ±80	1,020–1,310 cal AD	End of minerogenic level sediment.
137–142	Wood fragments	Ki-9760	980 ±70	950–1,220 cal AD	Start of minerogenic level sediment.
177–182	Wood fragments	Ki-8190	1,140 ±70	760–1,030 cal AD	Minerogenic level sedimentation
182–188	Wood fragments	Ki-8191	1,180 ±70	680–990 cal AD	Start of minerogenic level sediment.
243–250	Peat and silt	Ki-9768	1,360 ±70	540–830 cal AD	Start of minerogenic level sediment.
302–308	Peat and silt	Ki-9769	2,100 ±80	370 cal BC–60 cal AD	Start of minerogenic level sediment.
310–313	Wood fragment	Ki-9765	2,205 ±80	400–50 cal BC	Start of contaminated peat deposition
345–349	Tree trunk	Ki-9762	2,420 ±80	790–380 cal BC	Time of the depression creating
Profile 3					
44–50	Wood fragments	Ki-9171	620 ±80	1,260–1,440 cal AD	Start of minerogenic level sediment.
132–136	Peat	Ki-9172	980 ±80	890–1,230 cal AD	Start of minerogenic level sediment.
166–170	Peat	Ki-9173	1,290 ±80	610–900 cal AD	Minerogenic level sedimententation
180–182	Wood fragments	Ki-9766	1,170 ±80	680–1,020 cal AD	End of minerogenic level sediment.
225–230	Wood fragments	Ki-9767	1,320 ±70	600–890 cal AD	Start of minerogenic level sediment.

255–260	Wood fragments	Ki-9587	1,420 ±60	530–720 cal AD	Start of mineral level sediment.
300–320	Bark	Ki-9586	2,145 ±60	380–40 cal BC	Start of organic matter deposition
Profile 4					
39–43	Peat	Ki-8750	705 ±70	1,190–1,410 cal AD	Start of minerogenic level sediment.
94–100	Peat	Ki-8751	680 ±60	1,240–1,410 cal AD	Start of minerogenic level sediment.
187–190	Peat	Ki-8752	1,125 ±70	760–1,030 cal AD	End of minerogenic level sediment.
211–215	Peat	Ki-8753	1,390 ±80	430–820 cal AD	Start of minerogenic level sediment.
270	Wood fragments	Ki-8754	1,330 ±80	560–900 cal AD	Start of peat deposition
Northern peat bog (Fig. 2 — B)					
84–88	Peat with silt	Ki-7463	2,020 ±70	210 cal BC–140 cal AD	High energy deposits sedim. and start of peat deposition
Southern peat bog (Fig 2 — C)					
74–78	Wood fragm., peat	Ki-10046	420 ±60	1,410–1,640 cal AD	Start of minerogenic cover sediment.
143–147	Wood fragment	Ki-10045	850 ±70	1,030–1,290 cal AD	Start of peat deposition

In the profile 1, over the laminated sediments (peat-mineral) in the interval 2.2–1.6 m sandy silt with high content of sand and gravel (consisting of sandstones and variegated shales pebbles) occur (Fig. 3 — profile 1). In the neighbouring profile 2, complex of laminated peat-minerogenic sediments with pebbles at the top is a little bit lower in the interval 3.0–2.5 m. The top of this complex had been dated at 1,360 ±70 years BP (540–830 cal AD) (Fig. 3 — profile 2). However over it, to the depth 1.9 m in profile 2, continuous supply of allochthonous material (sandy silt) to the reservoir is seen (in the profile 1 at the same time sedimentation of sandy silt with gravel is continued). Organic material deposited here are strongly polluted with mineral material (only 20–30% of ignition loss) with two minerogenic layers (Fig. 3 — profile 2). The end of deposition of this series of allochthonous material supply was dated at before 1,180 ±70 years BP (680–990 cal AD) (Fig. 3 — profile 2). There is no level of laminated high-energy sediments with gravels in the profile most outlying from the alluvial fan (Fig. 3 — profile 3). Minerogenic deposits (weakly marked on LOI curve) occurring in strongly polluted bottom peat correspond with this complex. The upper part of gravel complex from profile 1, corresponds with sedge-moss fen peat with sharp lamina of minerogenic sediment dated at 1,420 ±60 years BP (530–720 cal AD) and over it gradual supply of allochthonous material to the peat bog is marked. This supply started at ca 1,320 ±70 years BP (600–890 cal AD) and was finished with deposition of lamina of minerogenic sediments dated at before 1,170 ±80 years BP

(680–1,020 cal AD) (Fig. 3 — profile 3). In the marginal profile of the peat bog (profile 4), this series corresponds with a thick (30 cm), homogenous minerogenic intercalation (sandy silt) deposited after ca 1,390 ±80 years BP (430–820 cal AD) (for the peat underlying the intercalation the date was: 1, 330 ±80 years BP; 560–900 cal AD) and finished before 1,125 ±70 years BP (760–1,030 cal AD) (Fig. 3 — profile 4).

Over the high-energy deposits the bed of sedge-moss fen peat (*Bryalo--Parvocaricioni, cariceto-bryaleti*) occurs, which in the neighbouring to alluvial fan profile is the most polluted with allochthonous material (vide Fig. 3 — profile 1). In the top of peat the next level of minerogenic sediments (sandy silt) (thickness: from 15 cm in profile 1, to 25 cm in profile 2 — vide Fig. 3) occurs. Time of sedimentation of this level in profile 2, was stated at ca 1,140 ±70 years BP (760–1,030 cal AD) and in profile 3, after ca 1,170 ±80 years BP (680–1,020 cal AD (the date 1,290 ±80 years BP; 610–900 cal AD, obtained in profile 3 from this minerogenic horizon, seems to be evaluated older than it really is — see Fig. 4). In the marginal profile (4) at the depth 1.4–1.5 m weakly marked illuvial level in the peat (30% LOI) corresponds with the above mentioned bed (Fig. 3 — profile 4).

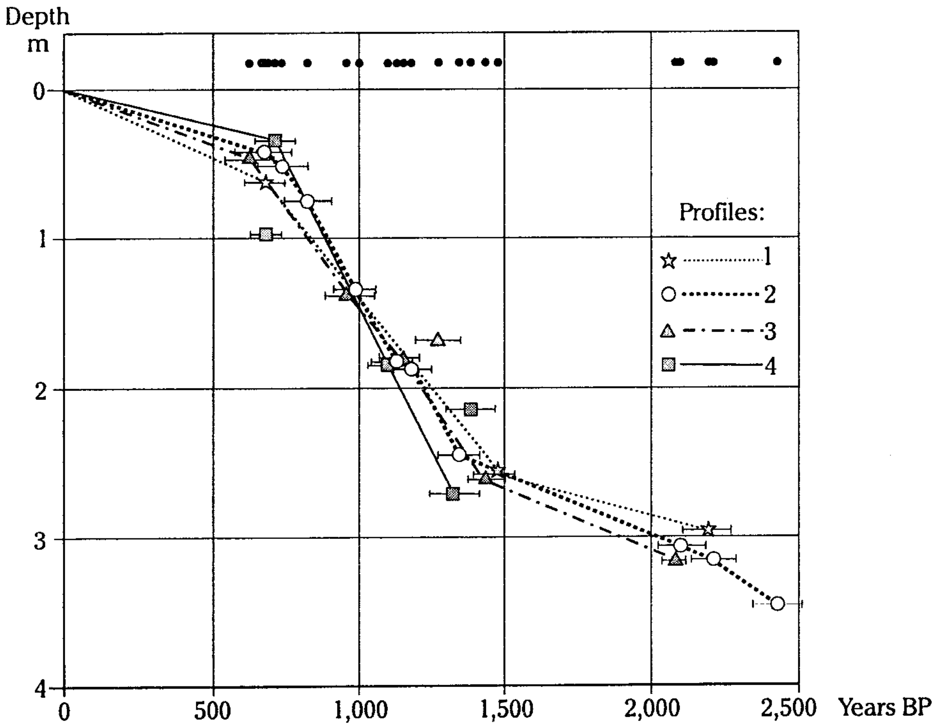

Fig. 4. Time-depth diagram from Ćwilin central peat bog (see Figs: 2 — A and 3) based on ^{14}C conventional (BP) datings (according to Berglund et al. 1996). Above: the distribution of radiocarbon datings (BP)

Over this minerogenic level deposition of sedge-moss fen peat is continued. Deposition was interrupted by weakly marked minerogenic level (silty clay and clayey silt) which occurs at the depth ca 1.4–1.3 m (vide Fig. 3 — profiles 1–3). The peat was dated at 980 ±70 years BP (950–1,220 cal AD) (profile 2) and 980 ±80 years BP (890–1,230 cal AD) (profile 3). Only in the profile neighbouring to alluvial fan (Fig. 3 — profile 1) within this level (not dated) sandy intercalation occurs and testifies high-energy character of deposition, so far.

The next intercalation of minerogenic deposits (clayey silt) is well visible in profile 2 where it was dated at 810 ±80 years BP (1,020–1,310 cal AD) and in profile 3, only illuvial level in peat corresponds with it. In the marginal profile (profile 4) considerable thickness (40 cm) of minerogenic bed (silty clay) corresponding with this level indicates, that it can be the notation of series of events which in other profiles form separate intercalations (dated in profile 2 at ca 980 and 810 years BP — see Fig. 3). The date obtained from the bottom of this level 680 ± 60 years BP (1,240–1,410 cal AD) seems to be evaluated younger than it really is (Fig. 3 — profile 4; Fig. 4).

The youngest minerogenic level (clayey silt in profile 1 and silty clay in profile 4) is best marked in the profiles distant from alluvial fan (Fig. 3 — profile 3). Radiocarbon datings obtained from this level are following: 740 ±80 years BP (1,150–1,410 cal AD) and 670 ±90 years BP (1,180–1,440 cal AD) (profile 2), 620 ±80 years BP (1,260–1,440 cal AD) (profile 3) and 705 ±70 years BP (1,190–1,410 cal AD) (Fig. 3 — profile 4). Numerous charcoals were found within this minerogenic level. In profile 1, charcoal fragment sampled on the depth 0.62–0.65 m, was dated at 680 ±70 years BP (1,220–1,410 cal AD) (Fig. 3 — profile 1).

DEPOSITS OF PERIPHERIAL PEAT BOGS

THE NORTHERN PEAT BOG

Thickness of deposits of small peat bog occurring at the foot of amphitheatre scarp is ca 2 m. Minerogenic sediments i.e. clayey silt stuffing up the depression occur in the interval 2.0–0.9 m. Above them thin gravel-sandy intercalations occur and on them, at the depth 0.88 m sedge-moss fen and sedge peat were deposited; in the interval 0.50–0.35 decomposed. The beginning of peat deposition was dated at 2,020 ±70 years BP (210 cal BC–140 cal AD).

THE SOUTHERN PEAT BOG

The southern peat bog (Fig. 2 — C) is shallow (ca 1.5 m). On the sandy silt in the interval 1.30–0.75 m, moss fen peat occur (locally decomposed), in places with addition of clastic material (at the depth 1.0–1.2 m). Minerogenic deposits (clayey silt) cover the peat (0.75–0.17 m) and at the top sedge-moss fen peat was deposited (Fig. 3 — southern peat bog). Fragment of timber taken from sediments which stuff up the depression (1.47–1.43 m) was dated at 850 ±70 years BP (1,030–1,290 cal AD). Radiocarbon dating of timber fragment occurring at the border between minerogenic cover and the peat shows that the cover was formed after 420 ± 60 years BP (1,410–1,640 cal AD) (Fig. 3; Table 1).

DISCUSSION

The radiocarbon date 2,420 ±80 years BP obtained from the trunk buried under the bottom sediments of central peat bog shows that the main phase of rejuvenation of the Ćwilin landslide (the central and northern peat bogs originated at that time) took place at the beginning of the Subatlantic. The process was the consequence of strong hydrometeorologic events connected with humidity growth and cooling of the climate at the beginning of the Subatlantic. Cooling of the climate caused glacial advances of the Goeschener 1 phase (Fig. 5) (Bortenschlager 1982) and climate humidity growth at that time caused particular increase of fluvial activity of Upper Vistula and its tributaries (Starkel 2002; Starkel et al. 1996) particularly the Raba River (Alexandrowicz and Wyżga 1992). High increase of mass movement activity in the Carpathians and in the majority of the European mountains was also registered in that period (Fig. 5) (Gamper 1993; Alexandrowicz 1996, 1997; Baumgart-Kotarba and Kotarba 1997; Starkel 1995, 1997; Margielewski 2000a, 2002; Ballantyne 2002; Dapples et al. 2002).

Concentration of calibrated radiocarbon datings of minerogenic levels of central peat bog as well as distribution of frequency of date occurrence in fifty-years periods show distinctly marked, two periods of series of hydrometeorologic events: 370–40 cal BC and 530–1,440 cal AD, and the younger period is divided into two parts: 530–1,050 cal AD and 1,150–1,440 cal AD (Fig. 5).

Deposition of older complex of high energy sediments within the central peat bog (370–40 cal BC) was connected with the same phase of humidity at the beginning of the Subatlantic, which caused rejuvenation of the landslide. The level of deposits connected with this climate humidity growth has also been marked in the northern peat bog: level of gravels under the peat was dated at 210 cal BC–140 cal AD (Fig. 5 — 1).

Younger complex with series of intercalations of high energy sediments (deposited in the period ca 530–1,440 cal AD) is distinctly lithologicaly bipartite. Its lower part (2.5–1.6 m in profile 1, and 3.0–1.9 m in profile 2) is characterised of permanent allochthonous material supply to the peat bog as well as of deposition of several series of high-energy sediments (laminated peat, gravel) (Fig. 3 — profiles 1–3). In the upper part of the complex (ca 1.9–0.0 m) thick (30–40 cm) levels of sedge-moss fen peat with several intercalations of minerogenic sediments were deposited (Fig. 3 — profiles 2, 3).

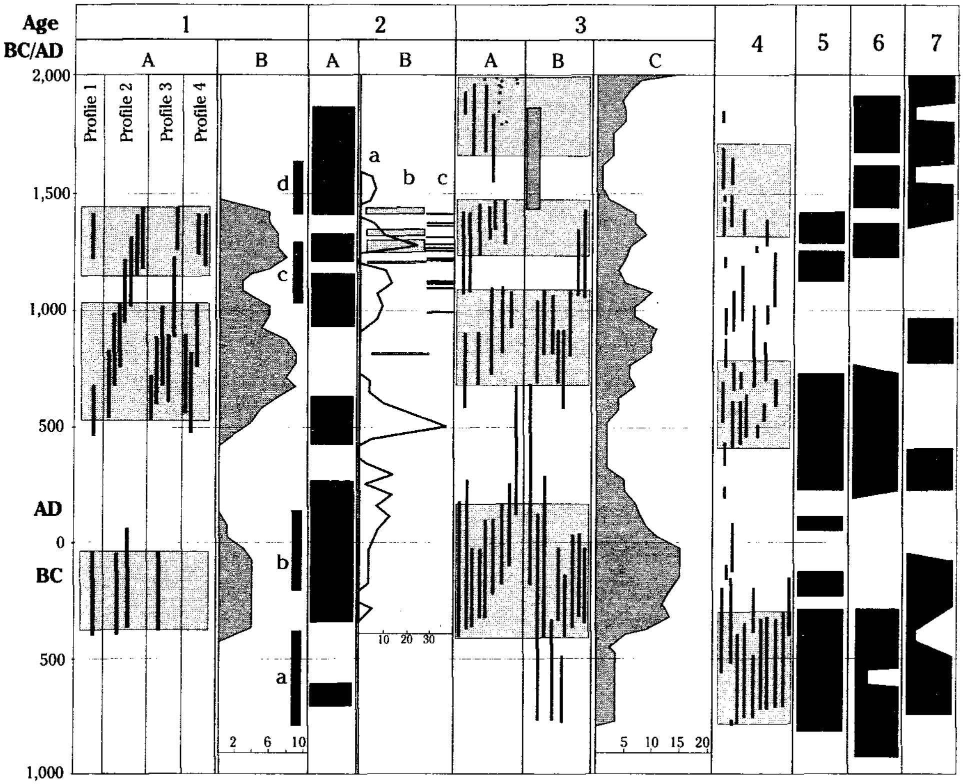

Fig. 5. The correlation of the events registered in the Ćwilin peat bogs, with climatic changes registered in European mountains (age: cal BC/AD, calibrated age: 94.5% confidence limits): 1 — events (minerogenic horizons) registered in analysed profiles in Ćwilin peat bogs (see Fig. 3): A — the distribution of calibrated age of minerogenic horizons in central peat bog (Fig. 2 — A, Fig. 3 — profile 1–4); B — the frequency of datings (from A column) in periods 50 yrs: grey vertical strips: a — age of the central peat bog (Figs. 2 — A, 3), b — high energy horizon in northern peat bog (Fig. 2 — B), c — age of the southern peat bog (Figs. 2 — C, 3), d — start of minerogenic cover sedimentation on southern peat bog (Fig. 3); 2 — Upper Vistula River actvity and their tributaries: A — phases of increased Upper Vistula River activity (Starkel et al. 1996); B — dated events in the Upper Vistula River: a — the frequency of falling oak trees in the Upper Vistula River valley (after: Krąpiec 1992, 1998; Kalicki and Krąpiec 1996); b — phases of oak falling registered in the Raba River valley (grey horizontal strips) (Danek and Krąpiec 2002), c — strong floods in the Upper Vistula River registered since AD 900 to AD 1500 (black horizontal lines) (Girguś and Strupczewski 1965); 3 — mass movements activity in the Polish Carpathians representing: A — dated landslides: by radiocarbon (callibrated age) and historic landslides (points) (Gil et al. 1974; Alexandrowicz 1996; Starkel 1997; Margielewski 1998, 2000a, 2002), B — minerogenic horizons in landslide's peat bogs (Margielewski 2000b, 2001b, 2002), and high energy deposits in the Tatra Lakes (grey vertical strip — increasing of debris flow frequency in Tatra Mts during the Little Ice Age) (Baumgart-Kotarba and Kotarba 1993, 1997), C — the distribution of calibrated age of mass movement (and historic landslides) in the Carpathians in the 50 yrs intervals (age from columns: A–B); 4 — mass movements activity in the Alps (after Dapples at al. 2002, suplemented by datings after: Porter and Orombelli 1981; Schoeneich et al. 1997; Corsini et al. 2001), 5 — solifluction in the Alps (Gamper 1993), 6 — glacier advances in the Alps (Bortenschlager 1982), 7 — phases of high water level in lakes of the SubAlpine range (Magny 1993)

Mean rate of deposition of sediments of lower part of younger complex is ca 3.2 mm/y (in the upper part is 2.8 mm/y) and considerably exceeds the rate of deposition of the Early Subatlantic, minerogenic level occurring below (rate ca 1.33 mm/y) (Fig. 4). Such a considerable increase of dynamics of sedimentary environment was caused by the particular increase of intensity and frequency of meteorologic factor occurrence in the period ca 530–1,050 cal AD. Therefore these phenomena marked in the sediments as clear series of events and their groups occurring as various lithologic complexes (gravel, sand, peat-minerogenic lamina) and their considerable thickness shows a longer time of deposition. The beginning of activity phase of alluvial fan (ca 530 cal AD) occurred in the phase of fluvial activity of the Upper Vistula (5^{th}–6^{th} centuries) (Starkel et al. 1996), dendrochronologically documented by the register of numerous black oak falls in the Vistula River valley (ca 425–625 AD) (Krąpiec 1992; Kalicki and Krąpiec 1996). In that period ca 1,480 ±60 years BP (430–660 cal AD) the increase of fluvial activity of the Raba River was recorded (Alexandrowicz and Wyżga 1992). During this climate humidity growth within Mount Ćwilin (central peat bog) laminated peat-minerogenic sediments (dated at 430–670 cal AD) and series of high energy deposits with gravels, were deposited (the end of deposition was in ca 530–720 cal AD). Deposition of upper minerogenic levels in that lower complex took place in ca 760–1,030 cal AD and is marked in a diagram of datings frequency as the distinct maximum (Fig. 5 — 1B). The beginning of the next phase of fluvial activity of the Vistula River dendrochronically dated at 900–1150 AD (Starkel et al. 1996) as well as dated by dendrochronology at ca 802 AD period of oak falls in the Raba River valley were registered (Danek and Krąpiec 2002).

In the analysed period in the mountain areas of Europe particular increase of mass movement activity was marked. In the Polish Carpathians intensity of those phenomena took place ca 600–1,100 cal AD (Fig. 5) (Baumgart-Kotarba and Kotarba 1993; Margielewski 2000b, 2001b, 2002). In the Alps this phase was dated at 400–800 cal AD (Fig. 5) (Gamper 1993; Schoeneich et al. 1997; Dapples et al. 2002) and is well correlated with cooling of the climate registered as the Goeschener 2 phase (Bortenschlager 1982). Moreover ca 700–900 AD high water level of lakes in the sub-Alpine Range (Petit Maclu phase) was registered and is the evidence of general increase of climate humidity at that time (Magny 1993) (Fig. 5).

Distribution of radiocarbon datings shows that the youngest set of minerogenic levels (and their illuvial equivalents) in the central peat bog under Ćwilin is the register of events from the period ca 1,150–1,440 cal AD (Fig. 5 — 1). The next rejuvenation of the landslide and formation of depression with the southern peat bog is connected with mentioned period (Figs. 2 — C and 5). During this period particular increase of frequency and intensity of floods were registered in the Carpathians. Phase of increase of fluvial activity of the Vistula River distinguished at that time (13^{th}–14^{th} centuries) was dendrochronically documented in detail by oak falls in the Vistula River valley ca 1200–1325 AD

(Krąpiec 1992, 1998; Starkel et al. 1996), particularly in the Raba River valley where series of oak falls took place in the following periods: 1250–1300 AD, 1320–1347 AD and 1419–1441 AD (Fig. 5 — 2) (Danek and Krąpiec 2002). Historical sources registered catastrophic floods in the upper part of the Vistula River valley and its tributaries AD 1219, 1221 particularly strong: AD 1253 and AD 1270 (series of floods in the Carpathians) the next in the years AD: 1280, 1310, 1359 and 1368 (Girguś and Strupczewski 1965) (Fig. 5). At that time the increase of fluvial activity of the San River ca 760 ±60 years BP (1,150–1,390 cal AD) was recorded (Szumański 1986). In the Polish Carpathians that period was marked by intensification of mass movement activity (Alexandrowicz 1993, 1996, 1997; Starkel 1995, 1997; Margielewski 2000a, 2001b, 2002). The increase of mass movement intensification was also registered within the Alps (Dapples et al. 2002) as well in the Scandinavian mountains (Blikra and Nemec 1998) and the Scottish mountains (Ballantyne 2002). Such strong intensity of hydrometeorologic phenomena was the result of cooling of climate (first oscillation of the Fernau Phase of glacial advances in the Alps — Bortenschlager 1982). Climate humidity growth accompanied by cooling of the climate caused the increase of fluvial activity of the European rivers (also the Vistula) and the increase of water level in the Alpine lakes (the first maximum of the Petit Clairvaux Phase — Magny 1993).

The youngest complex of minerogenic level within the central peat bog under the Ćwilin Mount is the result of recurrent heavy downpours which caused catastrophic floods in the Carpathians in the 13th and 14th centuries. Numerous charcoals occurring in the youngest minerogenic levels of the central peat bog (dated in profile 1, at 1,220–1,410 cal AD) show that not only hydrometeorologic conditions but also the anthropogenic conditions connected with mass deforestation and early Middle Ages colonization were the cause of intensive minerogenic sediments supply to the peat bog (see Starkel 1988; Margielewski 2000b). Therefore it is possible that particular minerogenic levels of that generation can represent single events of considerable intensity and longer duration (e.g. long-lasting or recurrent rains which caused several floods AD 1253 or AD 1270).

It is interesting that within the central peat bog there are deposits connected with strong cooling of the climate (and its humidity growth) in Little Ice Age (ca AD 1550–1850) which is perfectly well marked within the sediments of the Tatra lakes (Kotarba 1995). Also the phase of intensification of mass movements in the Carpathians, are also connected with this factor (Alexandrowicz et al. 1997). In that period sedge peat deposition took place. Probably that phenomenon resulted from the cutting of the rampart locking the water discharge of the peat bog (see Fig. 2 — A) and caused direction of discharge of water supplying the peat bog with allochtonic material. During the Little Ice Age, the cover formed of minerogenic material was deposited on the peat of the southern peat bog (Fig. 2 — C). The beginning of that sedimentation was dated at 420 ±60 years BP (1,410–1,640 cal AD).

CONCLUSION

Register of climatic changes of the Subatlantic within the peat bogs under the Ćwilin Mount is differentiated and comprises series of hydrometeorologic events as well as groups of single events which caused minerogenic material supply to the peat bogs. Datings show that the main stage of landslide rejuvenation (and formation of two landslide depressions) took place as a result of sudden humidity growth of the climate at the beginning of the Subatlantic. Hydrometeorologic phenomena connected with this humidity growth, later also caused sedimentation of the oldest minerogenic level in the central peat bog (370–40 cal BC) and the thin gravel level in the northern peat bog (210 cal BC–140 cal AD). The second complex of intercalations of minerogenic deposits within peat was formed at ca 530–1,050 cal AD and is a very distinct register of events' series and their groups. The time of its formation is well correlated with cooling of the climate in the Alps and with landslide phases in the Carpathians and the Alps as well as with the phase of the increase of fluvial activity of the Upper Vistula and the Raba rivers. Younger register of hydrometeorologic events dated at ca 1,150–1,440 cal AD is characterized of the occurrence of distinct groups of single, long-lasting events recorded in the deposits as distinct minerogenic and illuvial levels in the peat connected with heavy or recurrent downpours during early Middle Ages. Burning the forests within the landslide led to sedimentation of thick beds of minerogenic deposits in the youngest period. At that time the next phase of landslide rejuvenation and formation of the southern peat bog took place. Only within this peat bog characteristic of cooling of the climate of the Little Ice Age (minerogenic cover on the peat) sediments were deposited. The lack of deposits resulting from this coling period and humidity growth in the central peat bog may indicate that parallel to intensification of hydrometeorologic phenomena also the particular character of sedimentation environment (particularly changes in hydrologic regime) has the essential influence on the final register of climatic changes within the deposits.

ACKNOWLEDGEMENTS

The costs of the research were supportet by KBN Grants, No: 6P 04E 005 15 and No: 3P 04E 015 24. We'd like to thank to Dr Valentina Zernitskaya for pollen analyse and to Dr Krzysztof Lipka for analyse of organic deposits.

Włodzimierz Margielewski
Institute of Nature Conservation, Polish Academy of Sciences
al. A. Mickiewicza 33, 31-120 Kraków, Poland
margielewski@iop.krakow.pl

Nikolaj Kovalyukh
Kyiv Radiocarbon Laboratory
Institute of Environmental Geochemistry, National Academy of Sciences of Ukraine
34 Palladin Ave, Kyiv –142, 03680 Ukraine

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STRESZCZENIE

W. Margielewski, N. N. Kovalyukh

REJESTR ZMIAN KLIMATYCZNYCH NEOHOLOCENU W OBRĘBIE TORFOWISK OSUWISKOWYCH POD ĆWILINEM (BESKID WYSPOWY, KARPATY ZEWNĘTRZNE)

W obrębie osuwiska powstałego na zachodnim stoku Ćwilina (Beskid Wyspowy, Karpaty Zewnętrzne), rozpoznano 3 torfowiska z poziomami osadów minerogenicznych w torfach. Torfowisko centralne (datowane na początek fazy subatlantyckiej: 2420 ±80 BP) wypełnione torfami drzewnymi i turzycowo-mszystymi o miąższości 3,8 m, posiada kilka poziomów osadów minerogenicznych (pyły piaszczyste i pyły ilaste, lokalnie piaski i żwiry) związanych z aktywizacją stożka napływowego. Czas tworzenia się tych poziomów rozpoznano 25 datowaniami radiowęglowymi. Rozkład kalibrowanych dat radiowęglowych w okresach 50-letnich wskazuje, iż osady wysokoenergetyczne były deponowane w torfach w trakcie zwilgocenia klimatu ca 370–40 cal BC oraz ca 530–1050 cal AD (seria osadów ze żwirami), jak też ca 1150–1440 cal AD. Zdarzenia te dobrze korelują się z fazami wzrostu aktywności fluwialnej górnej Wisły i jej dopływów, jak też z fazami intensyfikacji ruchów masowych na obszarch górskich Europy, w tym szczególnie na obszarze Karpat i Alp. W trakcie depozycji młodszej serii poziomów minerogenicznych w torfowisku centralnym, wystąpiły odnotowane w źródłach historycznych szczególnie wielkie powodzie w XI–XIII wieku w Karpatach, obejmujące Rabę i Dunajec. Powstało wówczas kolejne torfowisko w zespole (południowe, o miąższości osadów 1,5 m), w którym na torfach zalega pokrywa osadów minerogenicznych (pył ilasty miąższości 0,6 m) datowana na ca 1410–1640 cal AD, a więc utworzona w trakcie ochłodzenia (i zwilgocenia) małej epoki lodowej. Ostatnie z rozpoznanych torfowisk (północne) powstało na początku fazy subatlantyckiej i jedynie w spągowych partiach torfów (0,9 m) występują tu osady wysokoenergetyczne datowane na ca 2020 ±70 BP powstałe w trakcie silnego zwilgocenia w tym czasie.