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LATE GLACIAL AND HOLOCENE CLIMATIC CHANGES REGISTERED IN FORMS AND DEPOSITS OF THE KLAKLOWO LANDSLIDE (BESKID ŚREDNI RANGE, OUTER CARPATHIANS)

Abstract. Radiocarbon datings, lithological analysis of sediments (loss on ignition) and palynologic analysis of the deposits filling up depressions of the Klaklowo lanslide (Beskid Makowski Mts), allowed to reconstruct the Late Glacial and the Holocene changes of the climate. The Late Glacial section of the profile of sediments (peat intercalated by mineral deposits) of the main depression, registered climate fluctuation since the Oldest Dryas to the Younger Dryas. Deglaciation at the beginning of the Holocene is marked on the profile as the mineral deposits in the peat bog. Observed hiatus (PB2–SB1) was the result of removal of the part of the Holocene deposits in effect of the climate humidity increase at the beginning of the Subboreal Phase. Two periods of sedimentation of the thick mineral cover on the peat were connected with climatic changes at the beginning of the Subatlantic Phase and in early Middle Ages. The rejuvenation of the lower parts of the landslide took place at the Early Subboreal, and the Late Subatlantic Phase.

Key words: landslide forms and deposits, palaeoclimate, the Late Glacial and the Holocene, radiocarbon datings, pollen analyse, Outer Carpathians, Poland

INTRODUCTION

Mass movements intensification in the Late Glacial and the Holocene has been related to the periodical increase in climate cooling and humidity rise (Starkel 1985, 1995a, 1995b, 1997; Alexandrowicz 1996, 1997). Existing datings of landslide forms and deposits performed in the Carpathians confirm the formation of numerous landslides (Alexandrowicz 1993, 1996; Margielewski 1997a, 1997b, 1998, 2000a) and intensification of the slope processes (Starkel 1995a, 1995b; Baumgart-Kotarba and Kotarba 1993, 1997; Kotarba 1996) in the above mentioned periods. There are only few localities in the Carpathians where periods of landslide reactivation connected with the phases of periodical increase of climate humidity were recorded. The landslide in Szymbark Kamionka in the Beskid Niski Mts is the best documented form (Gil et al. 1974; Starkel 1997). Several stages of succesive development of the landslide in Krynica were dated by the radiocarbon method

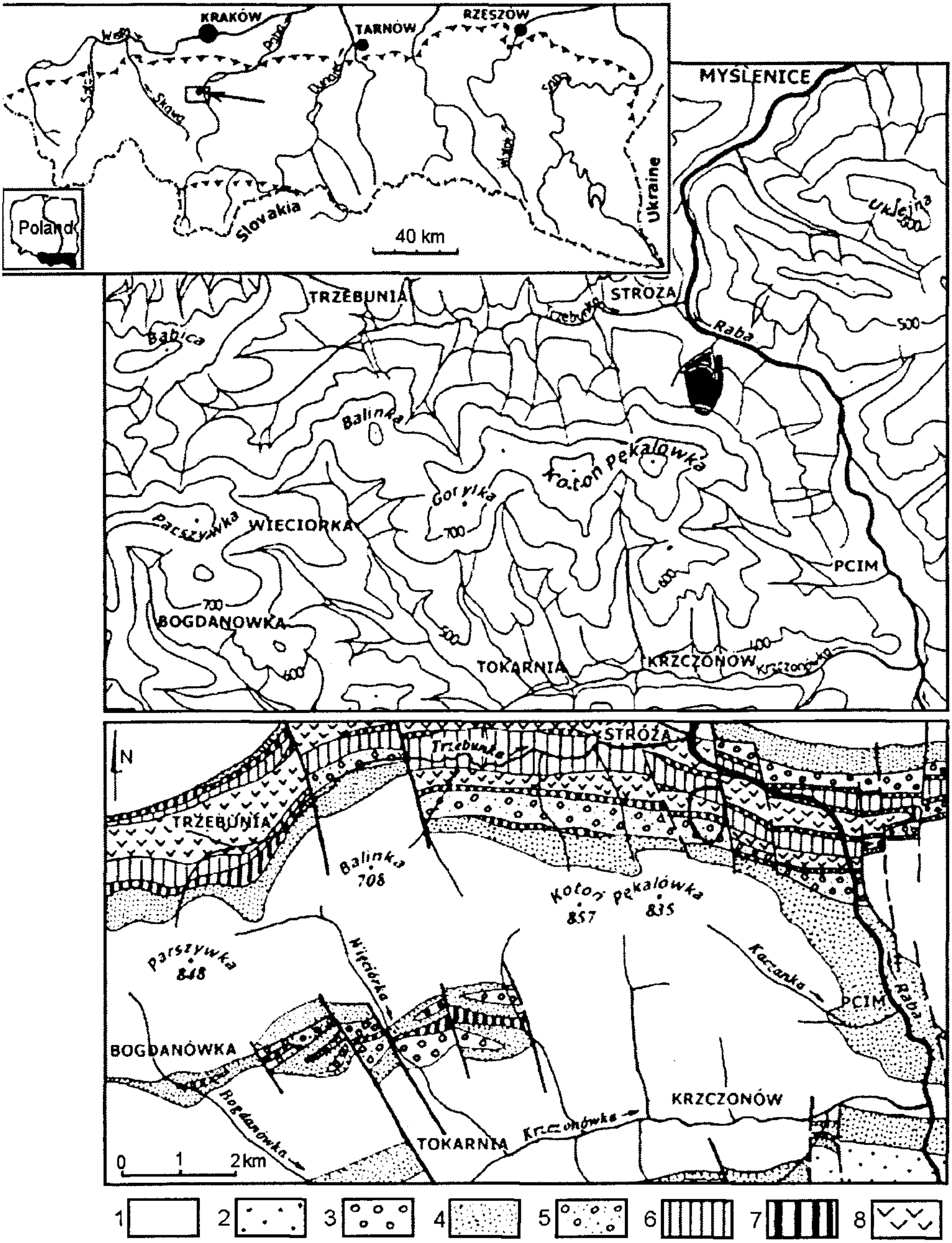

Fig. 1. Location of the Klaklowo landslide, with geological setting of the region. 1 — Magura Beds (glauconite facies), 2 — Magura Beds (muscovite facies), 3 — Upper Pasierbiec Sandstones, 4 — Hieroglyphic Beds, 5 — Lower Pasierbiec Sandstones, 6 — Ciężkowice Sandstones, 7 — variegated shales, 8 — Inoceramian Beds (after: Burtan and Szymakowska 1964; Wójcik and Rączkowski 1994)

(Alexandrowicz and Alexandrowicz 1999). The detailed analysis of sediments of lakes in the Tatras allowed to register the phases of slope destabilization. That process was connected with climatic changes in the Late Glacial and the Holocene when mineral (non-organic) high-energy sediments deposited in depressions (Baumgart-Kotarba and Kotarba 1993, 1997; Kotarba 1996).

The Klaklowo landslide is the next form where changes, connected with climate fluctuation during the above mentioned periods, were registered. The landslide in question is situated on the northern slope of Pękalówka Hill over Stróża village near Pcim (the Beskid Średni Mts) (Fig. 1). Radiocarbon datings and palynologic analysis of the deposits filling the landslide depressions, allowed to reconstruct the climate changes which occurred in the Late Glacial and the Holocene.

GEOLOGICAL SETTING

The Klaklowo landslide occurs within the Siary Zone of the Magura Nappe (Wójcik and Rączkowski 1994). Its upper parts were formed within the Lower Pasierbiec Sandstones (complex of sandstones and conglomerates), while lower parts are in the Inoceramian Beds (sandstones and shales) and the variegated shales (Fig. 1). The above mentioned sediments are underlying the thick-bedded Magura Sandstones of glauconite facies, which form the core and the northern limb of the Koskowa Góra–Kotoń–Pcim syncline. These sandstones also form the top parts of the Kotoń range (Burtan and Szymakowska 1964; Wójcik and Rączkowski 1994).

The landslide 700 m long and 300 m wide has the amphitheatre shape niche at 450 m a.s.l. and colluvium extending down to the lower parts of the stream valley, one of the left tributaries of the Raba River. The forms in question represents the multiple rotational landslide created in several stages, but main (the oldest) stage was probably developed as compound (rotational-translational) type (Dikau et al. 1996). It was in general developed as obsequent form in relation to attitude of beds (Fig. 2) (see Bober 1984).

Numerous depressions occurring in various parts of the landslide are filled with sediments. The vast subscarp depression dammed with characteristic colluvial rampart is connected with the main stage of the landslide development (Fig. 2 — depression A). Similar, although smaller landslide was formed during the main stage of rejuvenation of the form which previously existed in the middle part of the landslide zone (Fig. 2 — depression C). Number of trenches situated parallel to latitude and filled up with sediments are situated over that younger landslide. The trenches mark the stage of the landslide development (Fig. 2 — depression B).

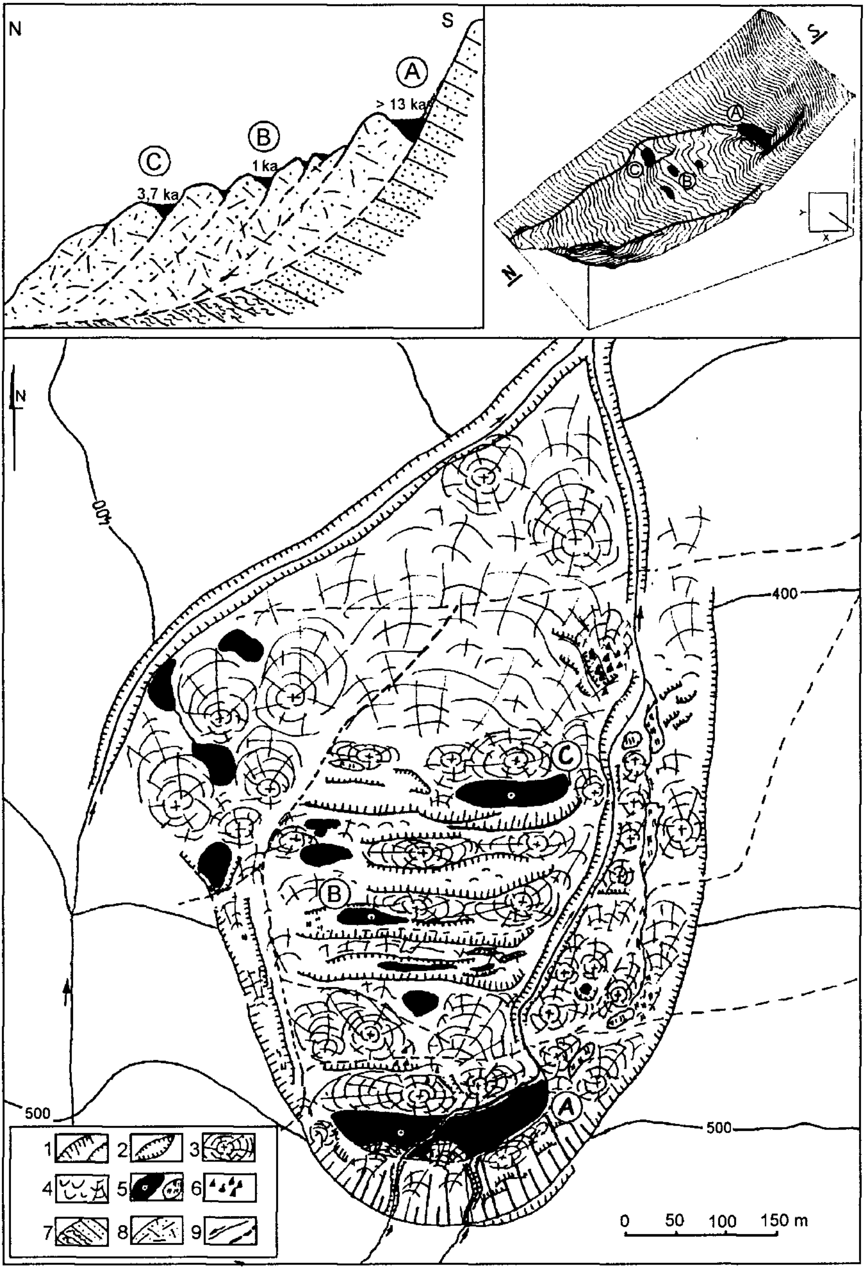

Fig. 2. Plan of the Klaklowo landslide with the cross-section and the orthogonal projection of hipsometry in Z value. A — depression connected with the main stage of the landslide formation, B–C — depressions connected with secondary landslides. 1 — niches and escarps, 2 — trenches, 3 — colluvial swells, 4 — colluvial surfaces and creeping, 5 — peat bogs (with the sampling places), and swamps, 6 — rocky blocks, 7 — sandstones and shales (on the cross-sections), 8 — mixed colluvial material (on the cross-sections), 9 — streams and roads

METHODS

Instorf driller (Russian driller) was used for sampling the sediments filling up the depressions. 33 drillings were done in the landslide zone. Sediments of 3 depressions i.e. subscarp depression connected with the formation of landslide (Figs 2 — depression A, 3) and two others formed during the rejuvenation of the landslide (Fig. 2 — depression B, C) have been elaborated in detail. Peat analyses were performed for the organic sediments (analysed by Dr. K. Lipka from Agriculture Academy in Kraków: peat classification after S. Tołpa et al. 1967). Areometric analyses by Casagrande method (modified by Prószyński) were done for non-organic (mineral) deposits and lithological classification according to F. P. Shepard (1954), using C. K. Wentworth's (1922) grain size scale. Loss on ignition at 550°C were analysed for 2.5 cm thick layers of the profile. Palynologic investigations of sediments were perfomed in the main subscarp depression (dr V. Zernickaya, the Institute of Geological Sciences of the Belarus Academy of Sciences, Minsk). Changes of pollen associations and of sedimentation were radiocarbonically dated in the Radiocarbon Laboratory in Kiev (Ki).

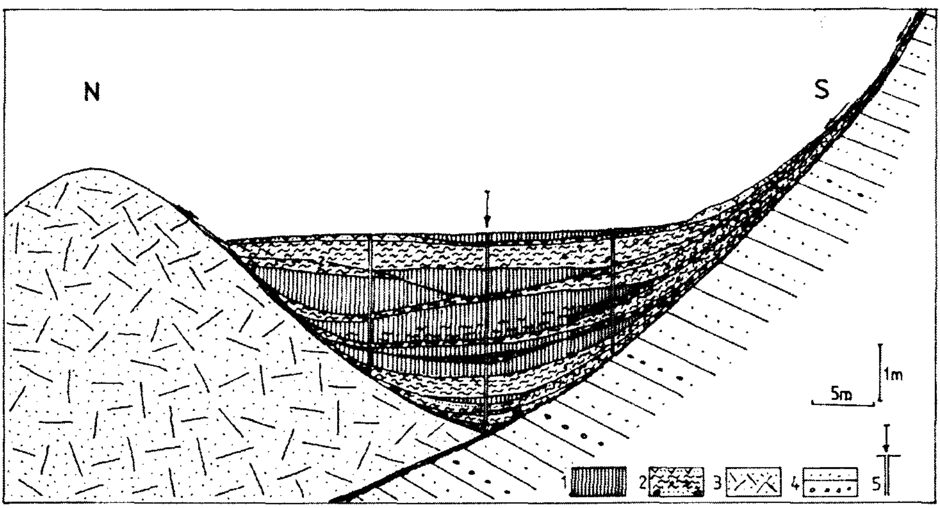

Fig. 3. The cross-section of the main depression filled by peat and fan deposits (see Fig. 2 — stage A). 1 — organic deposits, 2 — non organic (mineral) deposits, 3 — mixed colluvial material, 4 — sandstones and conglomerates, 5 — main profile (see Fig. 4)

SEDIMENTS OF SUBNICHE DEPRESSION

This depression (200 m long and 50 m wide) is connected with the main stage of the landslide formation. The scarp of a niche (about 70 m high) is at one side of the depression and the elongated colluvial rampart is opposite it

(Figs 2 — depression A, 3). Two vast alluvial cones are the typical element of the peat-bog in that depression. The cones spread on the area of a peat-bog. During the increase of climate humidity rise, non-organic deposits of cones

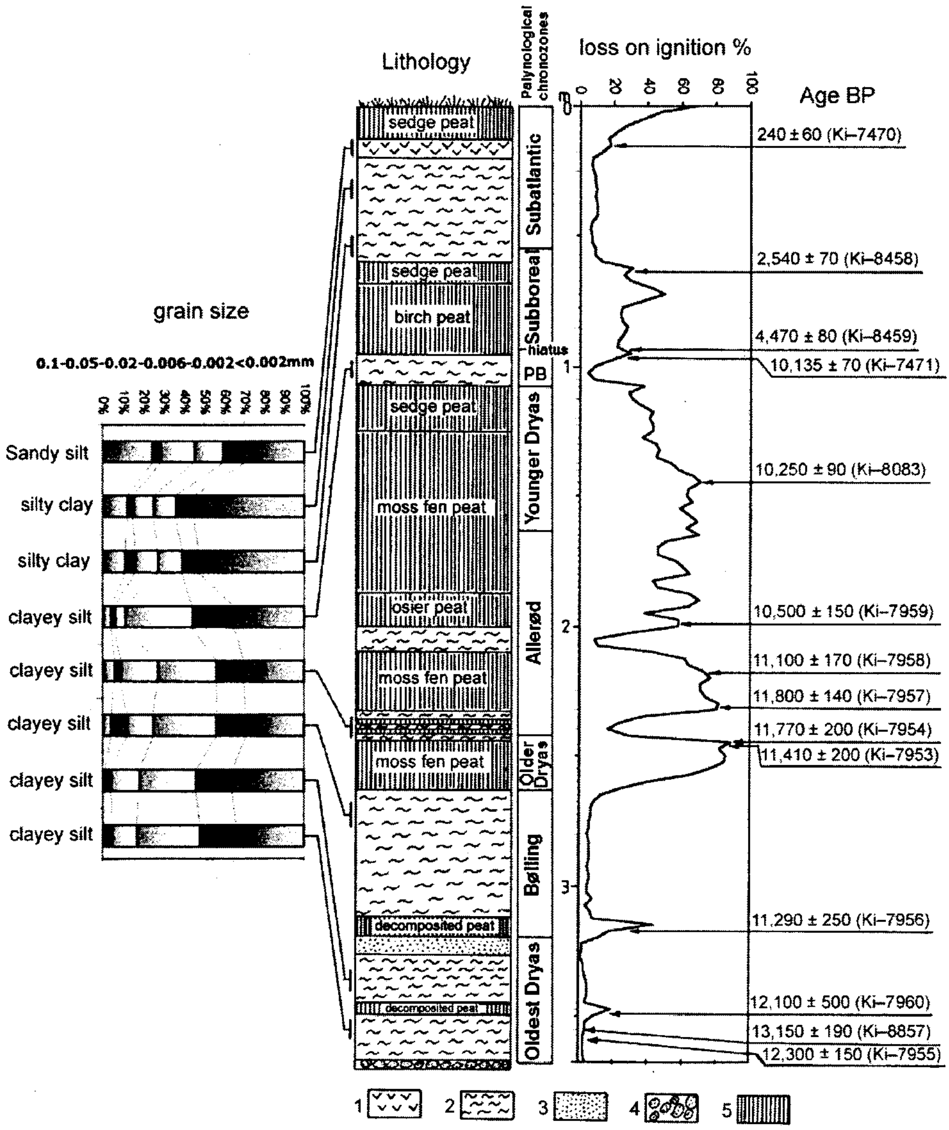

Fig. 4. The profile of deposits of main deppression of the Klaklowo Landslide (Figs. 2 — stage A, 3), with loss on ignition curve and palynological chronozones (analysed by V. Zernitskaya — see Fig. 5). Type of peat after K. Lipka analyse, grain size of mineral deposits after areometry (Casagrande's method), lithological classification after F. P. Shepard's (1954) classification. Conventional datings (BP) (Kiev Radiocarbon Laboratory). Lithology: 1 — sandy silt, 2 — clayey silt and silty clay, 3 — sand, 4 — gravels, 5 — peat

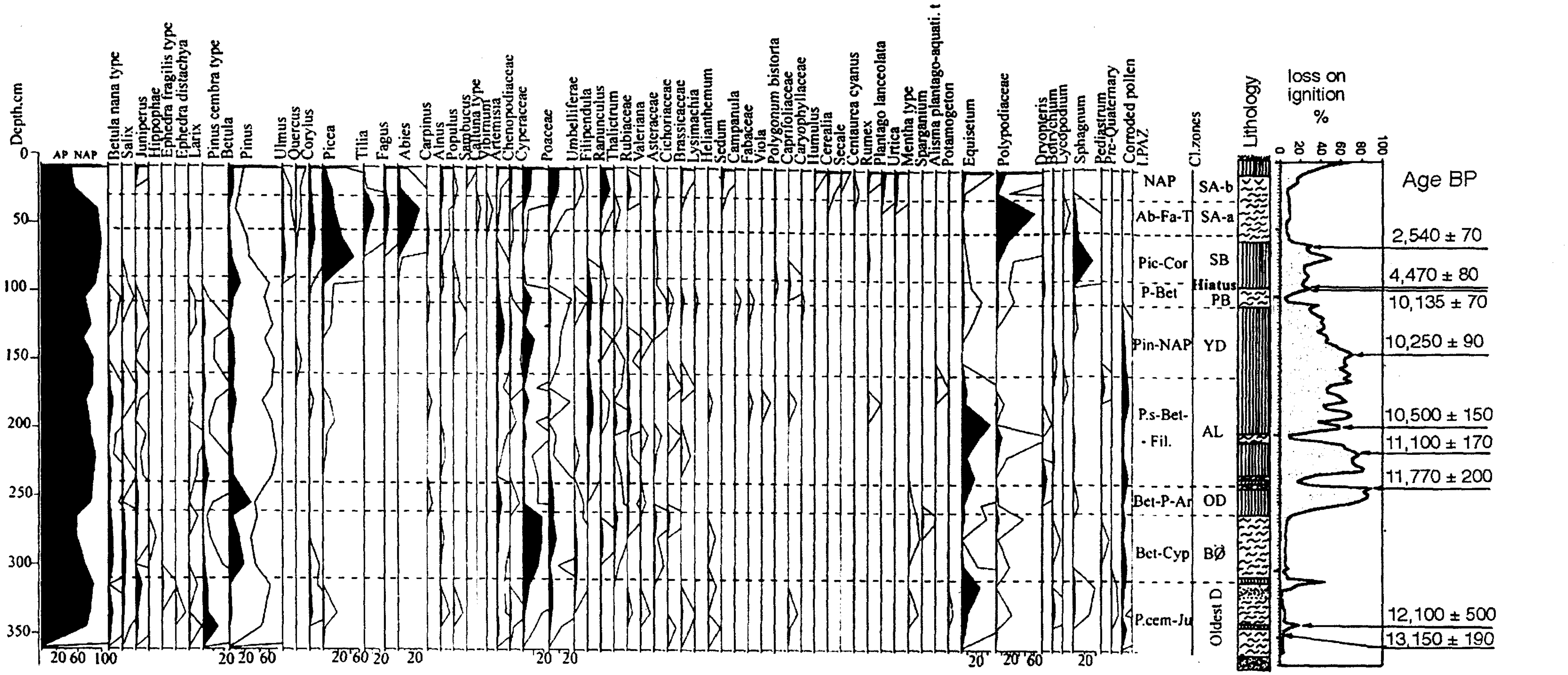

Fig. 5. Percentage pollen diagram from the profile of main depression Klaklowo landslide (analysed by Z. Zemitskaya) with the lithology and loss on ignition curve.
Explanation of the signature — see Fig. 4

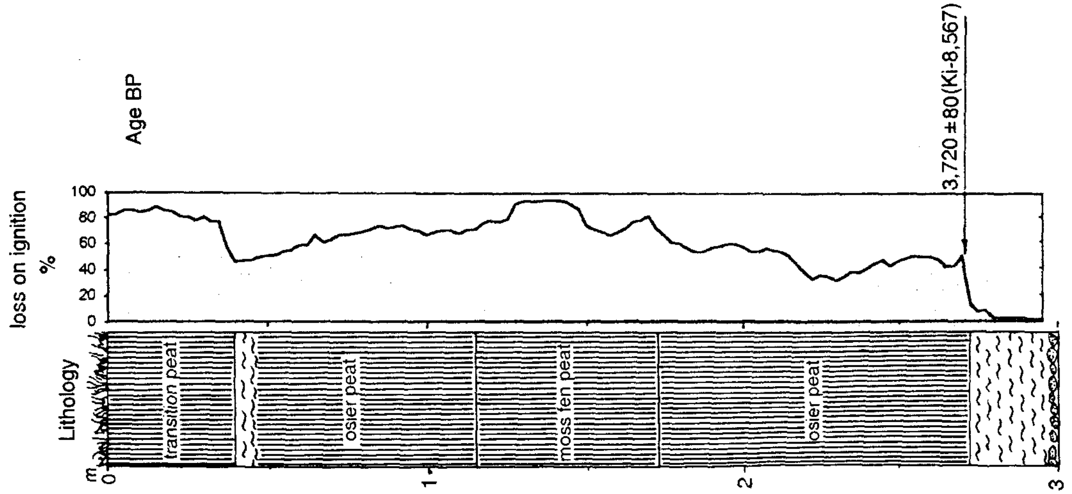

Fig. 6. Profile of deposits filling up depression connected with the main stage of the landslide zone rejuvenation (see Fig. 2 — stage C), with the loss on ignition curve.
Explanation of the signature — see Fig. 4

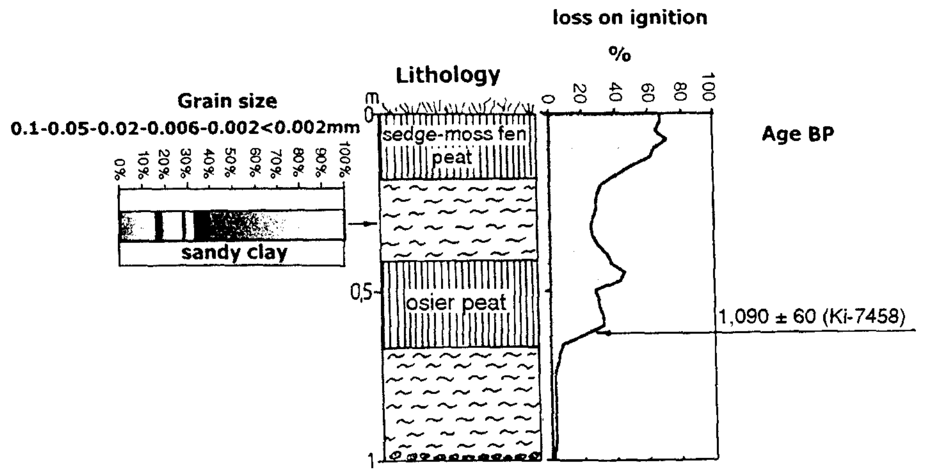

Fig. 7. Profile of deposits of the deppression connected with the youngest stage of the landslide zone development (see Fig. 2 — stage B), with the loss on ignition curve and areometry of the mi- neral deposits.
Explanation of the signature — see Fig. 4

periodically fed the peat-bog forming intercalations within organic sediments filling up the depression (Fig. 3).

17 drillings were performed to recognize the deposits of the above mentioned depression. In the deepest parts of the depression deposits are 3.75 m thick. Sediments represent the peat fens type intercalated with non-organic levels. Investigations of the loss on ignition enabled the detailed identification of the levels which marked climatic changes causing intensive supply sediments for the pool (see Baumgart-Kotarba and Kotarba 1993; Jonasson 1993; Kotarba 1996). Radiocarbon and palynologic dating of the level allowed to correlate these events with climatic changes during the Late Glacial and the Holocene (Figs 4, 5, 8).

The profile starts with clayey silt 0.25 m thick which is directly lying on the debris on the bottom of the depression. Organic material (detritus) taken from clayey silt occurring in the bottom of the depression, was dated by ^{14}C at 13,150 ± 190 years BP (Ki–8,857). Wooden fragment of birch was also found within this level and was dated by radiocarbon method at 12,300 ± 150 years BP (Ki–7,955). At the top of the clay level, at the depth of about 3.5 m, 7 cm thick intercalation of strongly contaminated and decomposed peat occurs (Fig. 4). The intercalation was radiocarbonically dated at 12,100 ± 500 years BP (Ki–7,960). Over this intercalation the next non-organic, mineral level occurs. It is formed of clayey silt (0.3 m thick) and over it sandy level containing sharp-edged debris is visibly. Sandy level marks the upper border of the Oldest Dryas, the period distinguished on the basis of palynological analysis (Fig. 5). Non-organic, mineral deposits especially sandy insert are typical of such type of climate cooling. Thin layer of strongly decomposed peat (3.10–3.16 m) above the mineral deposit is well marked on the ignition curve (40% of loss). It was dated at 11,290 ± 250 years BP (Ki–7,956) and as typical deposit of interstadial warming determines here the lower border of Bølling Phase recognized on the palynologic ground (Figs 4, 5). Both radiocarbon datings connected with the organic levels occurring within the lowest part of the profile, seems to be younger in relation to pollen analyse (Figs 4, 5).

Over this thin peat layer, clayey silt characteristic of cool climate occur. They form the remaining part of Bølling Phase (possibility of occurrence of such kind of deposits during that interstadial warming up was already registered — M. Ralska-Jasiewiczowa 1992). Sudden increase of ignition loss (reaching 80–90%) is marked on the curve at the depth of moss fen peat (*Bryalo-Parvocaricioni bryaleti*) accumulation. The increase continues up to ca 1.2 m depth (Fig. 4). In the depth interval 2.6–2.4 m climate cooling of the Older Dryas is marked on the pollen diagram (Fig. 5). Considering the character of deposits, the beginning of moss fen peat sedimentation was connected with warming up at the beginning of Allerød Phase. That can point out that the Older Dryas distinguished here is doubtful. Elimination or reduction of the Older Dryas in the area of the Alps was suggested by M. Welten (1982). In Allerød Phase when moss fen peat sedimented, two sharp minima connected with non-organic intercalations occurred and they are marked on the ignition curve. The first intercalation at the depth 2.3–2.4 m, is formed of characteristic mineral-peat (clayey silt-moss fen peat) layers ca 1 cm thick (Figs 4, 5). The bottom (peat) of the layer was double dated at 11,770 ± 200 BP (Ki–7,954) (fragment of wood) and at 11,410 ± 200 BP (Ki–7,953) (peat), and its top (fragment of wood) was dated at 11,800 ± 140 BP (Ki–7,957). Similar deposits typical of the Allerød Phase (ca 11.8 ka BP), were described from the Ropa River terrace in Wysowa (Wójcik 1997).

In general mineral-organic, laminated deposits within the deposits of the Tatra lakes were described as typical sediments of the Bølling and the Allerød Phases warmings (Baumgart-Kotarba and Kotarba 1993; Obidowicz 1996). This level within the Klaklowo peat bog is discontinuous and limited to the fragment of the deepest part of the reservoir (Fig. 3). Next argillous intercalation (clayey silt) 8 cm thick on the ignition curve is marked at the depth about 2 m (Fig. 4). Its bottom was dated at 11,100 ± 170 BP (Ki–7,958) and its top at 10,500 ± 150 BP (Ki–7,959). 15 cm thin layer of osier peat (*Alnioni saliceti*) occurs above this layer. At the interval referring to the depth 2.0–1.6 m the rhythmic supply of mineral (non-organic) sediments is marked on the ignition curve. Both episodes of mineral sediments supply are connected with two climatic events which were registered in the Allerød Phase, they are marked as double decrease of the temperature at that period (Fig. 8). Also two episods of the Upper Vistula River activity were registered in the period (Starkel (ed.) 1996; Starkel and Gębica 1995) (Fig. 8).

The Younger Dryas was recorded as the slow decrease of organic matter participation in the interval ca 1.6–1.0 m which was caused by cyclic mineral (non-organic) supply to the reservoir as well as the start of sedge peat (*Magnocaricioni cariceti*) sedimentation (Fig. 4). However radiocarbon datings point out that the Holocene deposits are at the depth ca 1.4 m (their age is 10,250 ± 90 BP — sample no Ki–8,083). The beginning of consequent non-organic sediments supply is connected with this border. This is reflected with gradual decrease of the ignition curve and ended with clay intercalation, palynologically dated at the Preboreal Phase (Figs 4, 5). Above this deposit, the layer of birch woody peat (*Betulioni betuleti*) occurs. It has the sedge peat at the top. Between mineral (non-organic) sediment and peat, the hiatus from the Preboreal Phase (clayey silt) to the Subboreal Phase (woody peat) is marked on the pollen diagram (Fig. 5). Radiocarbon datings obtained from the bottom of this peat (90 cm) confirm this. The beginning of peat sedimentation was dated by radiocarbon method at 4,470 ± 80 (Ki–8,459) and fragment of the wood sampled from the border between clay and peat at the depth 95 cm was dated at 10,135 ± 70 BP (Ki–7,471) (Fig. 4). Both facts confirm the Preboreal age of the argillous insert.

Next, this time thicker (ca 0.5 m) level of mineral sediments represented by silty clay with thin layer of sandy silt at the top represents the deposit from the beginning of the Subatlantic Phase according to the palynologic analyses (Figs

4, 5). The age of this deposit is confirmed by radiocarbon date obtained from the top of peats from under the clay and is dated at 2,540 ± 70 BP (Ki–8,458).

The youngest radiocarbon dating 240 ± 60 BP (Ki–7,470) points out the beginning of sandy silt sedimentation typical of contemporary occurrence of debris covers. This date can be rejuvenated by the roots of contemporary plants. Thin layer of sedge peat (*Magnocaricioni cariceti*) occurs above non-organic deposits.

FORMS AND DEPOSITS CONNECTED WITH THE STAGES OF LANDSLIDE REJUVENATION

Stages of the Klaklowo landslide rejuvenation are connected with the younger phases of the Holocene. During the main phase of rejuvenation, in the lower parts of the landslide the form with the set of amphitheatrically situated niches emerged (Fig. 2C). At their foot the vast depression filled up with peat was formed. Thickness of the deposits is ca 3 m (Fig. 6).

On the bottom silts (3.0–2.8 m) the following layers occur: osier peat (*Alnioni saliceti*) (2.8–1.7 m), moss fen peat (*Bryalo-Parvocaricioni bryaleti*) (1.7–1.1 m), above — the next osier peat (1.1–0.4 m). Transition peat with *Sphagnum palustre* ca 0.4 m thick are at the top of the peat bog (Fig. 6). The beginning of woody peat sedimentation was radiocarbonically dated at 3,720 ± 80 BP (Ki–8,567) which can point out the relation of this landslide with the early Subboreal Phase. Probably this phase of rejuvenation of a zone could be connected with the events at the beginning of the Subboreal Phase which caused erosive removal of part of sediments filling up the main sub-niche depression.

The curve of ignition loss made for this profile has indistinct minima only (Fig. 6). The most distinctive minimum of the curve appeared at the depth ca 0.5 m and can be associated with non-organic sediments supply to the reservoir caused by some younger episode of climate humidity rise, possibly ca 2 or 1 ka BP. Maybe that formation of numerous shallow trenches contemporarily filled up with mineral-organic deposits above the niche of this landslide was connected with that humid period (Fig. 2 — depression B). Radiocarbon date 1,090 ± 60 BP (Ki–7,458) pointed this out. The date was obtained as the effect of dating the beginning of peat sedimentation (osier peat — *Alnioni saliceti*) occurring at the bottom parts (0.6–0.4 m) of the biggest and lowermost situated depression in this trenches set (Figs 2 — depression B, 7). In this profile, above the thin level of peat (at the interval 0.4–0.1 cm) on the ignition curve exists the minimum connected with sedimentation of the thin cover of sandy clay probably connected with humid period ca 1 ka BP (Fig. 7). Thin layer of sedge-moss fen peat (*Bryalo-Parvocaricioni cariceto-bryaleti*) occurs above non-organic deposits (Fig. 7).

CLIMATIC CHANGES REGISTERED INSIDE THE KLAKLOWO LANDSLIDE

Complex of events comprising the Late Glacial i.e. the Oldest Dryas–the Younger Dryas and the Holocene was registered within the Klaklowo landslide (Figs 4, 5). During the Late Glacial the most distinctive changes are connected with the end of the Oldest Dryas (sand deposit) as well as with two distinctive climate fluctuations in the Allerød inter-phase when supply of mineral sediments to the reservoir took place (Fig. 4). Cyclic increase of non-organic sediments supply to the peat bog at the beginning of the Holocene, and its end during the Preboreal Phase by sedimentation of clay are characteristic of this profile (Fig. 4). Intensive production of organic matter reflected in peat sedimentation was usually related to the Preboreal warming (Koperowa 1962; Ralska-Jasiewiczowa 1989; Lindner (ed.) 1992; Obidowicz 1996). Inside characteristic landslide reservoirs, steep and high niche was conducive to high energy processes causing aboundant supplies of allochtonic material to the reservoir. Movement of slope covers resulting from the post-Pleistocene deglaciation (Starkel 1991, 1995a) at first caused reduction and then interruption of peat sedimentation (Late-Glacial peat) as a consequence of intensive supply of non-organic deposits to the reservoir.

On the palynologic diagram the late glacial vegetation is dominated by steppe-tundra complex with small participation (locally bigger) of *Cyperaceae, Graminae* as well as *Pinus, Betula* and (smaller) *Juniperus* (Fig. 5).

Hiatus in the palynologic profile of the Klaklowo landslide is extremely interesting and unique for so far analysed palynologic profiles from the Carpathians and their foothills. In the analysed profile it corresponds with the period from the Boreal to Subboreal Phases and is undoubtedly of erosive character. It is difficult to accept the fact that such a long gap in sedimentation (ca 5,000 years) would be caused by overdrying of a reservoir in the Atlantic Phase so favourable to peat sedimentation (Ralska-Jasiewiczowa and Starkel 1988). Probably at the beginning of the Subboreal Phase (ca 4.5 ka BP) dissection and removal of a part of deposits took place within the Klaklowo peat bog. The depth of the dissection reaching the younger phase of the Preboreal Phase can vary in different parts of the peat bog in the profile under the question. Probably the main stage of the landslide rejuvenation in its lower parts dated at 3.7 ka BP (Fig. 2 — depression C) is connected with this period.

Similar hiatus preceding the sediments of earlier Subboreal Phase was also found in two other palynologically elaborated profiles of the peat bogs in the Beskid Makowski Mts: Hajduki (upper part of the Ziębówka stream near Pcim) and the one on the southern slopes of Mount Kotoń (Margielewski 1997b, 2000b, 2001). That can point out the great scale of climate changes occurring at the beginning of the Subboreal Phase (Starkel 1995b).

The period of the early Subboreal humidity of climate as reflected in the Carpathians in numerous landslides formation (Margielewski 1998, 2000a) as well as in occurrence of non-organic intercalations within organic deposits

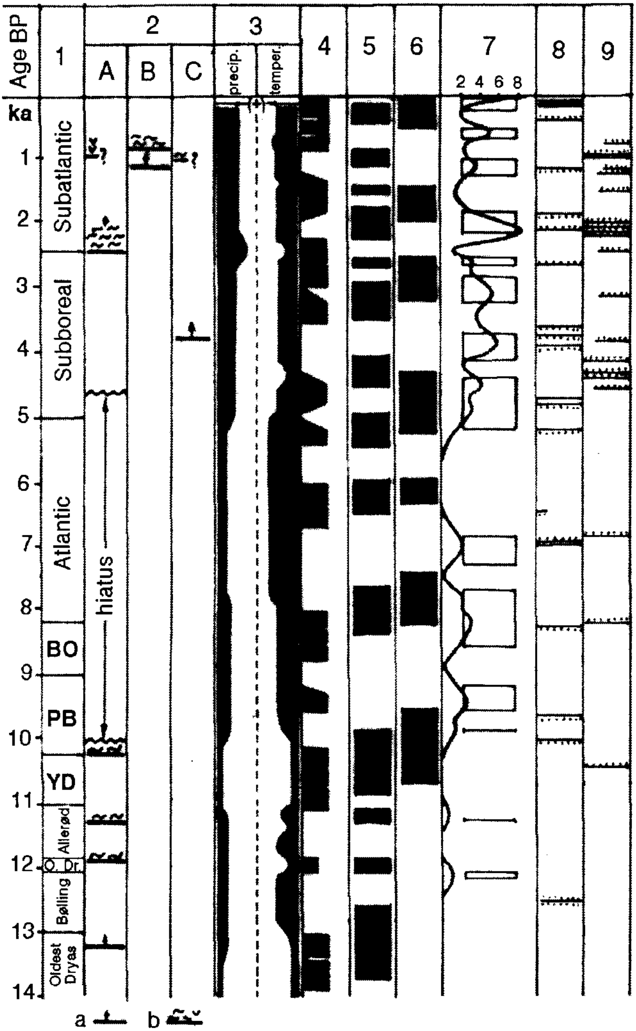

Fig. 8. Events registered in the forms and deposits of the Klaklowo landslide, on the background of the chosen palaeoclimatic changes during the Late Glacial and the Holocene, registered in various forms and deposits in Central Europe. 1 — chronozones (Starkel 1990; Orombelli and Ravazzi 1996), 2 — events registered inside deposits and forms of Klaklowo landslide (stages A, B, C — see Fig. 2): a — stages of the landslide development, b — high energy deposits, 3 — paleoclimate (Orombelli and Ravazzi 1996; Goudie 1992, modified by Corsini et al. 2000), 4 — glacial advances in Alps (Bortenschlager 1982), 5 — phases of the Upper Vistula River activity (Starkel (ed.) 1996), 6 — landslide phases in the Carpathians (compilation after Starkel 1995a, 1997, Alexandrowicz 1996), 7 — the frequency of the landslide's radiocarbon datings (in time intervals 250 years) with the landslide phases (*sensu lato*) in the Carpathians (datings after various authors, compiled by Margielewski 2000a, 2000d), 8 — mineral levels in the Tatra lakes sediments (Baumgart-Kotarba and Kotarba 1993, Kotarba 1996), 9 — mineral levels in the landslide's peat bogs in Beskid Makowski Mts and Beskid Wyspowy Mts (Margielewski 2001, Margielewski and Kovalyukh 1998, 2000)

of the Tatra lakes (Baumgart-Kotarba and Kotarba 1993; Kotarba 1996), in the Szymbark landslide's peat bog (Gil et al. 1974; Starkel 1997) and in the Beskid Makowski Mts peat bogs (Margielewski 2000d, 2001). High climate humidity rise ca 4.4–4.1 ka BP caused the next phase when the increase of the Upper Vistula fluvial activity took place (Kalicki 1991; Starkel 1993–1994, Starkel (ed.) 1996). The increase of water level in lakes was synchronously marked in the lakes of northern Poland (Ralska-Jasiewiczowa 1989; Starkel et al. 1996) as well as in sub-Alpine lakes qualified as the Chalain Phase (Magny 1993). Strong cooling of climate during this period affected the increase of mountain glacial advances in the Alps (Rotmoos–2 Phase, Piora Phase — Patzelt 1977; Zoller 1977) and in Scandinavia (Karlen and Kuylenstierna 1996) (Fig. 8).

On the palynologic diagram, above the hiatus, together with the development of deposits of the Subboreal Phase appears the consequent decrease of curves of *Pinus* and *Betula* with gradual development of forest associations with *Picea* and stenothermal *Ulmus*, *Corylus*, and later *Abies alba*, *Fagus* and *Tilia* (Fig. 5).

The age of the next non-organic level was palynologically and radiocarbonically defined. The level forms compact cover on peat (clay and silty clay) and points out the deposits connexion with strong, widespread humidity rise and cooling of the climate during the beginning of the Subatlantic Phase (ca 2.3–1.8 ka BP). Cooling of climate was commonly reflected in Europe in the form of fluctuations of glacial advances in the Alps during Goeschener 1 and Goeschener 2 Phases (Patzelt 1977; Bortenschlager 1982) as well as in Scandinavia (Karlen and Kuylenstierna 1996). The phase of increase of fluvial activity of the European rivers, particularly of the Upper Vistula was distinctly registered at that time ca 2.3–1.8 ka BP (Starkel (ed.) 1996). Mineral/non-organic covers or intercalations of organic sediments of that period are common within numerous peat bogs occurring on landslides in the Beskid Makowski Mts and the Beskid Wyspowy Mts (Margielewski and Kovalyuk 1998, 2000; Margielewski 2000c, 2000d, 2001). In the deposits of the Tatra lakes inserts of non-organic sediments as the result of high-energy processes were also registered during this period (Baumgart-Kotarba and Kotarba 1993, 1997). Strong rise in humidity of the climate during this period generated formation of numerous landslides in the Carpathians. Presently the landslide phase (sensu lato) ca 2.3–1.8 ka BP is the best documented by numerous radiocarbon datings from the Carpathians (Alexandrowicz 1996, 1997; Margielewski 1997a, 1998, 2000a).

Parallel to the climate conditions, the intensive supply of allochtonic matter to the Klaklowo peat bog and sedimentation of thick non-organic cover connected with the beginning of the Subatlantic Phase could be of anthropogenic origin. In the middle part of the sediments of the Subatlantic mineral cover in the main depression of Klaklowo, various charcoals were found. That can point out the intensive deforestation of the Beskid Makowski Mts already confirmed in numerous localities (Margielewski 2000b, 2001). Burning the forests in the Carpathians could be connected with the development of the Celtic civilization and confirmed by numerous localities of the La Tene culture (Valde-Nowak 1988; Madyta-Legutko 1996). On the palynologic diagram gradual increase of the curves for plants preferring open communities (*Chenopodiaceae, Rumex, Plantago lanceolata, Urtica, Sedum*) with the decrease of the curve for *Picea* is visible at that time (ca 2 ka BP) (Fig. 5).

The next episode connected with the change of the climate ca 1 ka BP is marked in the Klaklowo landslide as changes in sedimentation when the sandy silt in the deposit cover of the main depression replaced sandy-silty clay (Fig. 4). The phase of rejuvenation of the lower parts of the landslide took place at that time. It was dated at ca 1.09 ka BP, non-organic matter was supplied to all analysed reservoirs then (Figs 4, 6, 7). Up till now, such kind of changes in alluvial sedimentation (i.e. sandy clay instead argillous clay occurred) in the Vistula River valley were attributed to the increase of anthropopression ca 1 ka BP (Klimek 1988; Starkel 1988, Starkel (ed.) 1996; Alexandrowicz 1992). Human activity coincided with strong cooling and humidity rise of the climate which generated the first stage of the Alpine glaciers advances of the Fernau Phase (Bortenschlager 1982) and also the periodic increase in fluval activity when the Vistula river activity was registered in the time interval 0.9–1.0 ka BP (Starkel (ed.) 1996). At that time the phase of landslide intensification *sensu lato* in the Carpathians (Margielewski 1998, 2000a) and the younger phase of mineral cover accumulation on the peat of the Beskid Makowski Mts (ca 1 ka BP) were registered (Margielewski 2000b, 2001) (Fig. 8).

On the palynologic diagram anthropopression is marked as the full development of plants preferring open communities. Development of *Chenopodiaceae, Urtica, Plantago lanceolata* took place (Fig. 5). Simultaneously sudden diminution of *Tilia, Fagus* and *Abies* curves points out the strong deforestration what is confirmed by occurrence of numerous charcoals in the deposits. Pollens of corns (*Secale*) and weeds (*Centaurea cyanus*) appeared there (Fig. 5).

CONCLUSION

Large scale changes of climate connected with the Late Glacial and the Holocene were distinctly marked within the forms and deposits of the Klaklowo landslide. Late Glacial section of the profile of sediments of the main depression contains continuous record of lithologic changes which were connected with climate fluctuations registered in the sediments since the Oldest Dryas to the Younger Dryas (Figs 4, 5). Destabilization of slope covers as the result of deglaciation at the beginning of the Holocene is marked on the profile as the consequent supply of non-organic deposits to the reservoir. Sedimentation of non-organic level ended this process (Fig. 4).

Changes of the climate in the Holocene were synchronously marked within the deposits of the main depression as well as in the stages of landslide rejuvenation. There are no deposits of the Atlantic Phase in the profile under the question. Observed hiatus was the result of removal of the part of the Holocene deposits (PB–SB1) conditioned by hydrometeorologic high energy processes controlled by strong changes of climate conditions at the beginning of the Subboreal Phase (Figs 4, 8). The rejuvenation of the lower parts of the landslide took place at that time. Two cycles of sedimentation of the thick non-organic cover on the peat were connected with climatic changes at the beginning of the Subatlantic Phase and in Early Middle Ages. Rejuvenation of the zone with next landslides is also connected with the youngest episode ca 1 ka BP.

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STRESZCZENIE

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ZAPIS ZMIAN KLIMATYCZNYCH PÓŹNEGO GLACJAŁU I HOLOCENU W FORMACH I OSADACH OSUWISKA KLAKLOWO (BESKID ŚREDNI, KARPATY ZEWNĘTRZNE)

Na północnym skłonie Pękalówki ponad Stróżą w pobliżu Pcimia (Beskid Średni), występuje rozległe osuwisko datowane na najstarszy dryas, przekształcane później w kilku etapach. W obrębie form osuwiskowych i osadów wypełniających zagłębienia koluwialne, wyraźnie zaznaczyły się zmiany klimatyczne, związane z późnym glacjałem i holocenem. Datowanie radiowęglem poziomów zmienności osadów, identyfikowanych na krzywych strat prażenia, jak również analiza palinologiczna osadów głównego zagłębienia, pozwoliły na odtworzenie rejestru zmian klimatycznych w późnym glacjale i holocenie. Późnoglacjalny odcinek profilu osadów zagłębienia związanego z głównym etapem kształtowania osuwiska, zawiera ciągły zapis okresowych zmian klimatycznych zarejestrowanych od najstarszego dryasu po fazę preborealną. Początek holocenu i związane z nim uruchamianie pokryw stokowych w wyniku ustępowania wieloletniej zmarzliny, zaznaczył się w profilu konsekwentną dostawą osadów mineralnych (pył ilasty) do zbiornika, zakończoną sedymentacją poziomu mineralnego. Zmiany klimatu w holocenie, zaznaczyły się synchronicznie w obrębie osadów zagłębienia głównego, jak również w formie kolejnych etapów odmłodzeń osuwiska. W analizowanym profilu z procesami wysokoenergetycznymi na początku fazy subborealnej, był związany hiatus w profilu torfowiska głównego, spowodowany prawdopodobnie erozyjnym wymieceniem części osadów holoceńskich (PB–SB1), jak również faza odmłodzenia dolnych partii osuwiska młodszą formą datowaną na 3,7 ka BP. Dwa cykle sedymentacji grubej pokrywy mineralnej na torfach były związane ze zwilgoceniami klimatu, zaznaczającymi się na początku fazy subatlantyckiej, jak również we wczesnym średniowieczu.