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DATED LANDSLIDES OF THE JAWORZYNA KRYNICKA RANGE (POLISH OUTER CARPATHIANS) AND THEIR RELATION TO CLIMATIC PHASES OF THE HOLOCENE

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Abstract: Ten radiocarbon datings of landslides of the Jaworzyna Krynicka Range, were performed to establish the date of their formation or rejuvenation. These datings widen the documentation of the landslide phases connected with humid periods of the Holocene. Several dates correspond to landslide phases and prove that the landslides were formed at the beginning of the Atlantic Phase, termination of the Subboreal Phase, in the Middle Ages and at the beginning of the Little Ice Age. A landslide phase of mass movement intensification connected with a humid phase at the beginning of the Subboreal Phase is based on two radiocarbon datings. Five radiocarbon dates confirm the relationship between mass movement intensification and a humid phase distinguished at early Subatlantic Phase.

Abstrakt: W obrębie osuwisk pasma Jaworzyny Krynickiej wykonano dziesięć datowań radiowęglowych, pozwalających na określenie czasu powstania lub odmłodzenia tych form. Datowania te znacznie poszerzają dokumentację faz osuwiskowych w Karpatach, wiązanych z okresami holoceńskich zwilgoceń. Część uzyskanych dat dokumentuje okresy intensyfikacji osuwisk wydzielane na początku fazy atlantyckiej, w schyłkowym okresie subborealu oraz w średniowieczu, we wczesnej fazie małej epoki lodowej. Faza osuwiskowa wiązana z okresem wilgotnym na początku subborealu jest potwierdzona dwoma datowaniami. Pięć datowań radiowęglowych potwierdza związek intensyfikacji ruchów masowych z fazą zwilgocenia wydzielaną we wczesnym subatlantyku.

Key words: Polish Outer Carpathians, Holocene, mass movements, radiocarbon datings, landslide phases.

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INTRODUCTION

Mass movements are among the prevailing processes in relief evolution of the Carpathians because of their characteristic geological structure (Starkel, 1960; Ziętara, 1962, 1964; Nemčok, 1982; Bober, 1984; Kotarba, 1986). The intensity of these processes was connected with humid periods in the Holocene which indicates the periodic development of the Beskidy Mts relief (Starkel, 1985, 1986, 1990). The age of the mass movements has not been appropriately established. The relatively small number of precisely dated landslide sediments has until now made the task of reconstructing and documentating the landslide phases in the Carpathians particularly difficult. This fact is connected with difficulties in gaining of proper material for dating. Palinological, malacological or radiocarbon analyses of organic sediments were used when determining the age of the Carpathian landslides. These sediments fill up the depressions within the landslides or occur in barrier lakes resulting from damming up a river by the colluvia (Gil *et al.*, 1974; Alexandrowicz, 1993b).

This paper presents eight landslide forms of the Jaworzyna Krynicka Range (Magura Nappe, Polish Outer Carpathians), where organic sediments fill up the depressions (subniche or intercolluvial ones). Ten radiocarbon dates obtained from wood occuring at the bottom of these sediments allowed to fix the date of formation or rejuvenation of the landslides and enabled to supply more complete documentary evidence for the mass movement phases, distinguished in the Carpathians by Starkel (1985) and Alexandrowicz (1993b).

Radiocarbon datings were made in the Radiocarbon Laboratory of the Silesian Technical University in Gliwice (Gd) and in the Institute of Nuclear Physics of the Academy of Mining and Metallurgy in Kraków (Kr). Analytical costs were paid by the State Commitee for Scientific Research (KBN) (research project 6P 202 007 04).

GEOLOGICAL SETTING

The Jaworzyna Krynicka Range is the eastern fragment of the Beskid Sądecki Mts, bordered by the valleys of the Poprad and the Kamienica Nawojowska rivers. Geologically, it is situated within the inner structural subunits of the

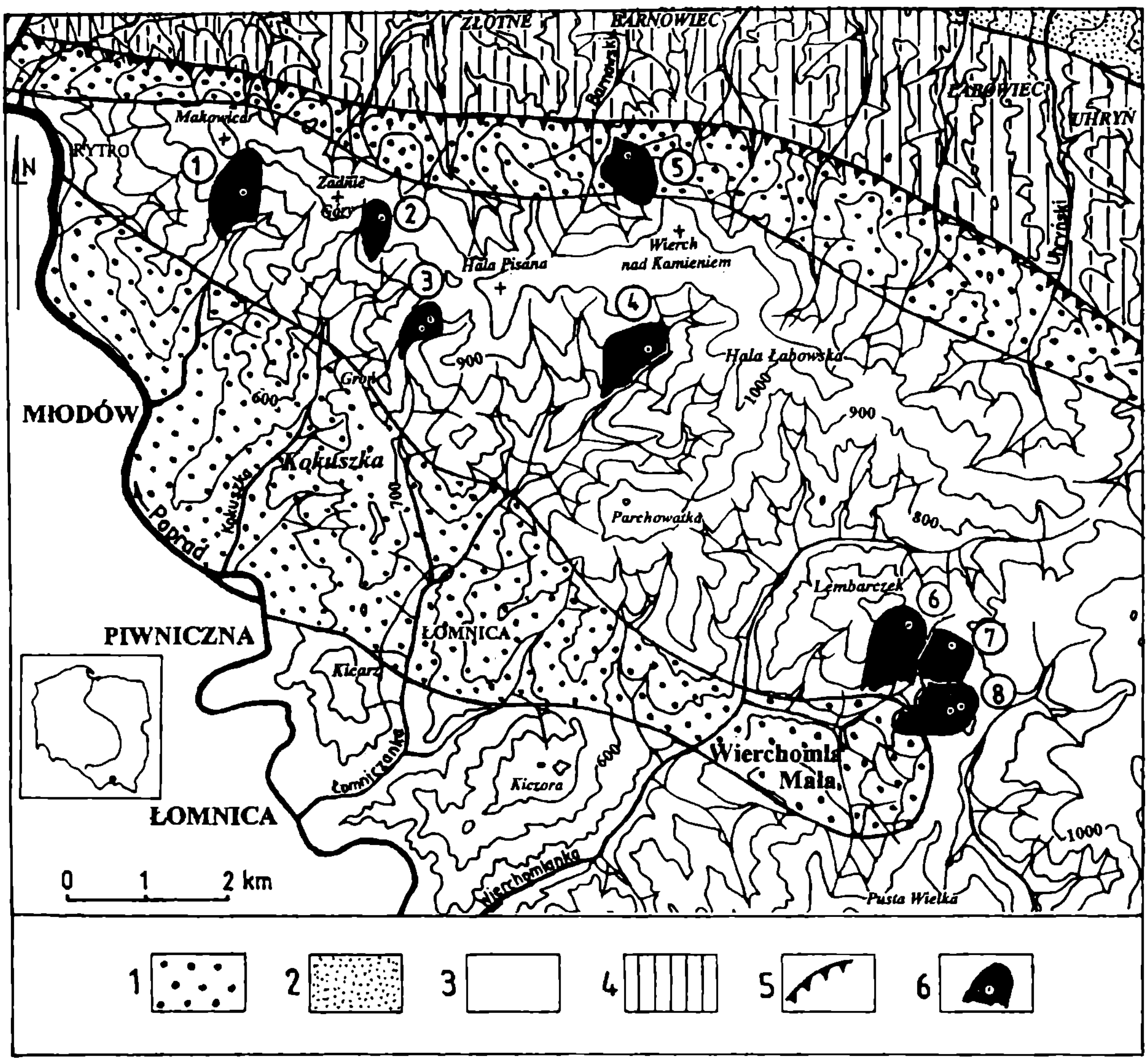

Fig. 1. Dated landslides of the Jaworzyna Krynicka Range and geological overview of the region (geology after Birkenmajer & Oszczypko, 1989; Oszczypko, 1991). *1* – Szczawnica and Zarzecze Formations, *2* – Beloveza Formation, *3* – Piwniczna Member, Magura Formation, *4* – Maszkowice Member, Magura Formation, *5* – Krynica overthrust, *6* – dated landslides with placement of samples for radiocarbon analysis: 1 – Cyrla, 2 – Gaworzyna, 3 – Jesionowa, 4 – Świniarnia, 5 – Wierch nad Kamieniem, 6 – Wierchomla 1, 7 – Wierchomla 2, 8 – Wierchomla 3

Magura Nappe: the Sącz Subunit (Bystrica Subunit) and overthrusted from the south by the Krynica Subunit (Świdziński, 1953; Węcławik, 1969) (Fig. 1). The zones consist of Upper Cretaceous–Paleogene flysch deposits (mainly turbidite formations) which are about 3000 m thick (Birkenmajer & Oszczypko, 1989; Oszczypko, 1991).

The main ridge of the range is 1 000 m a.s.l.. It was formed of the Krynica Subunit deposits, represented by the Piwniczna Sandstone Member of the Magura Formation (thick bedded sandstones packaged of thin and medium bedded flysch). It is underlained by flysch sediments of the Zarzecze Formation, consisting of thin and medium bedded sandstones with conglomerates and pebble mudstones of the Krynica Member (Birkenmajer & Oszczypko, 1989; Oszczypko *et al.*, 1990) (Fig. 1). These deposits build the main geological structure of this range, called Runek–Łabowska Hala–Pisana Hala Sincline. Zarzecze formation is underlained by the deposits of the Szczawnica Formation represented by the conglomerates (Życzanów Member), thin and medium bedded flysch with dark shales (Birkenmajer & Oszczypko, 1989; Oszczypko *et al.*, 1990). The northern part of the Jaworzyna Krynicka Range (side ridges) is occupied by the Bystrica Subunit, which is distinguished from the Krynica Subunit mainly by the presence of the Łącko marls in the Żeleźnikowa Formation (thin and medium bedded flysch) and Maszkowice Member of the Magura Formation (thick bedded sandstones packaged of thin bedded flysch) (Oszczypko, 1991) (Fig. 1).

LANDSLIDES OF THE JAWORZYNA KRYNICKA RANGE

Mass movements played an important role in the relief transformation of the Jaworzyna Krynicka Range. They caused its lowering and dismembering. The strong expansion of valleys and the development of valley head systems initiated these processes. Landslide distribution is strictly dependend on the geological structure. Particularly tectonic anisotrophy (fissures) of the sandstone massif, and changes of lithology as well as technical parameters of the sandstones controll the distribution of landslides (Margielewski, 1997). In the Jaworzyna Krynicka Range they form numerous associations characterised by frequent successive rejuvenation (Margielewski, 1994c). All of the studied landslides represent a type of structural rock slide. They were formed in the sandstones of the Piwniczna Member of the Magura Formation or within sandstones and conglomerates of the Krynica Member of the Zarzecze Formation (Fig. 1).

CYRLA LANDSLIDE

The wide mass movement zone with numerous landslides was formed on the southern slope of Mount Makowica near Rytro (Fig. 1.1). In the central part of the zone there is a hillside, consequent-slip landslide resulting from the lateral erosion of the Głęboczanka stream. It has relatively high, contemporarily creeped niche with typical margin troughs. Varied colluvium was formed at the foot of the niche (Fig. 2). It forms numerous swellings, ramparts divided by trenches and depressions. Organic deposits fill up one of the holes without the outflow situated in the lower part of the colluvium. A peaty mass is the main component of 2 m thick sediments (Fig. 6.1). There are overturned trunks aged 2020 ±100 yrs BP (Gd-10161) at the bottom part of the analysed depression (Margielewski, 1994b). The date fixes the time of the youngest stage of the Cyrla landslide zone formed by mass movements.

GAWORZYNA LANDSLIDE

At the valley head of the Jaworzyna stream, on the western slope of Mount Gaworzyna (963 m a.s.l.), an obsequent, pack-rotary landslide was formed (Fig. 1.2). A double-ridge is its main element (Margielewski, 1994a). Traces of two landslide generations are visible. An older generation gave a rectilinear set of niches and a loosened rocky pack (double-ridge) and a younger phase, during which rejuvenation of the main niche took place, a high escarp system was formed. During the landslide rejuvenation, at the foot of the set of niches, a narrow, 1.2 m deep trench was formed and filled up with grey-blue and brown, sandy silt covered with dark organic silt (Fig. 6.2). Samples of wood fragments (detritus) from the base of the deposits record an age of 1580 ±130 yrs BP (Kr-151). The date approximately fixes the time of rejuvenation of the Gaworzyna landslide (Margielewski, 1994a, b).

JESIONOWA LANDSLIDE

A set of sucessive landslides formed by several mass movement generations occurs on one of the southern side-ridges deviating from the main top, in the area of the Hala Pisana (Pisana Alm) (Margielewski, 1994b) (Fig. 1.3). Older stages of the landslide are related to the headward erosion of the Łomnicka stream. Lateral erosion of the stream initiated the rift-trench situated in the lower part of the landslide. The landslide represents a consequently-fissure, pack-debris type in the upper part and a pack-rotary type in the lower, rejuvenated part. During one of the mass movement stages, in the upper part of landslide, a hole related to sub-niche depression was formed (Fig. 3.1). At present it is filled with 2.8 m thick, organic sediments (brown organic silt with peaty mass) (Fig. 6.3) (Margielewski, 1994b). Wood sampled from trunks at the base of this sediment was dated at 7260 ±110 yrs BP (Gd-4957).

During the following, younger mass movement stage, a

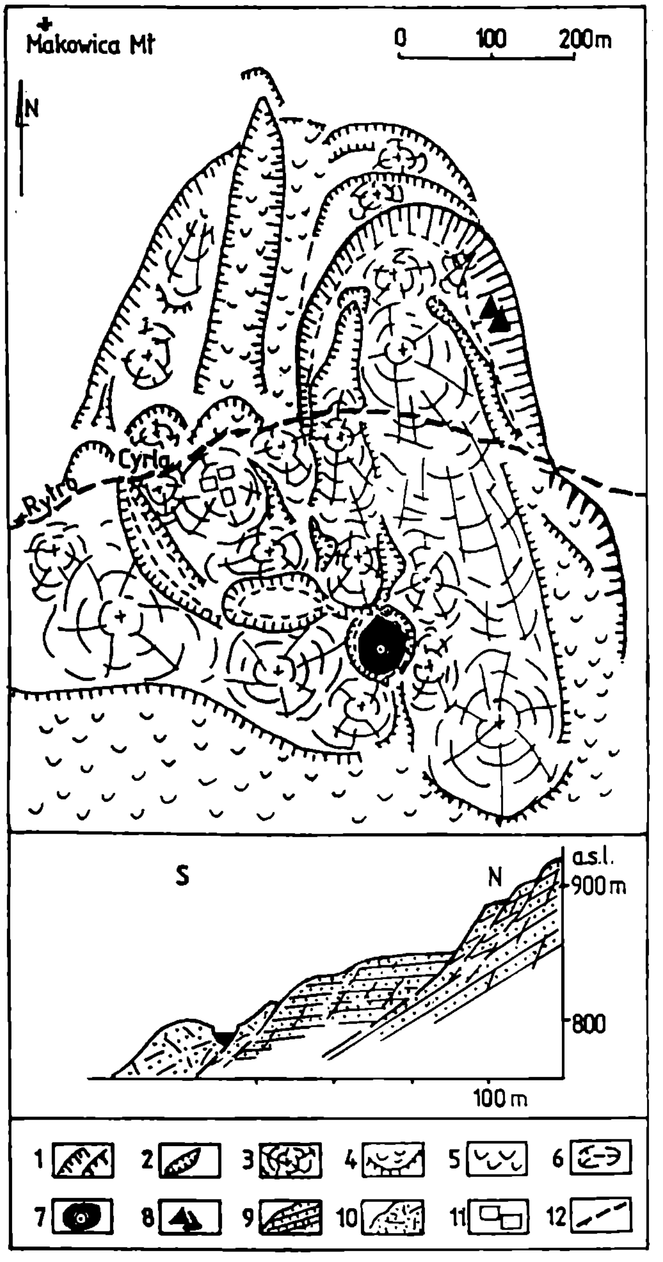

Fig. 2. Sketch and schematic cross-section of the Cyrla landslide (see Fig. 1.1): *1* – niches, *2* – trenches, *3* – colluvial swells and tongues, *4* – colluvial steps, *5* – creeping, *6* – colluvial depressions without outflows, *7* – peat bogs with sampling sites, *8* – rock boulders, *9* – Magura sandstones (in the cross sections), *10* – mixed colluvial mass (in the cross-sections), *11* – buildings, *12* – road

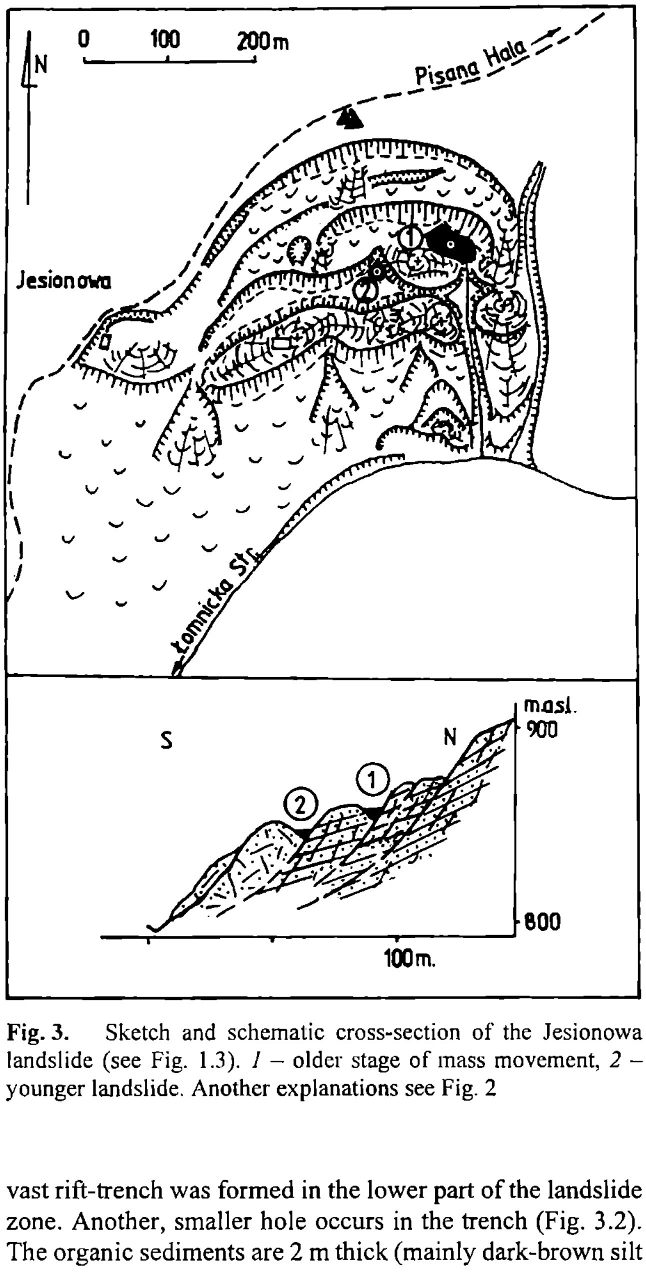

Fig. 3. Sketch and schematic cross-section of the Jesionowa landslide (see Fig. 1.3). *1* – older stage of mass movement, *2* – younger landslide. Another explanations see Fig. 2

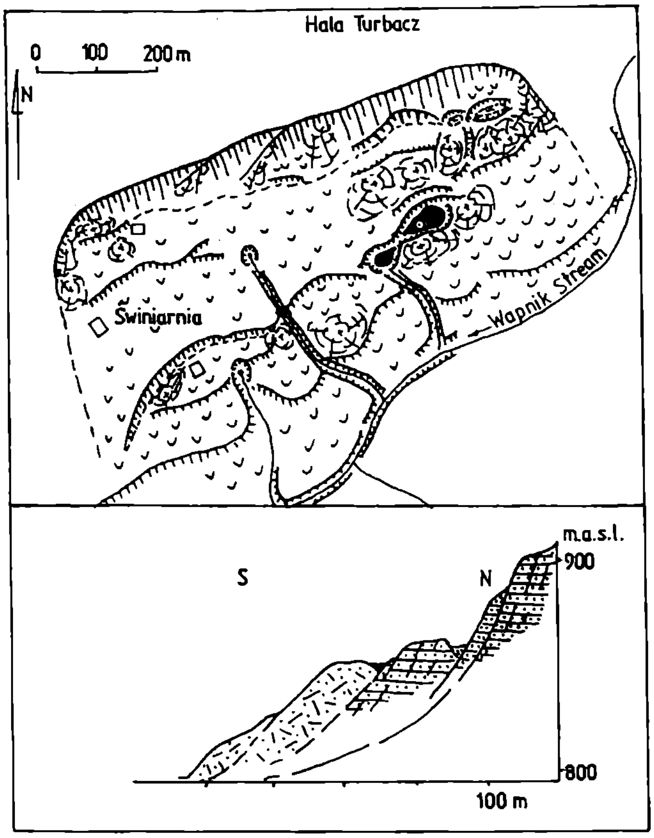

Fig. 4. Sketch and schematic cross-section of the Świniarnia landslide (see Fig. 1.4). Explanations see Fig. 2

vast rift-trench was formed in the lower part of the landslide zone. Another, smaller hole occurs in the trench (Fig. 3.2). The organic sediments are 2 m thick (mainly dark-brown silt with a peaty mass) (Fig. 6.4). Wood fragments sampled from trunks situated at the bottom part of sediments, record an age of 4790 ±90 yrs BP (Kr-150) (Margielewski, 1994b). Both dates of the set of the Jesionowa landslide reveal the timing of landslide zone rejuvenation during particular mass movement stages. The Jesionowa landslide zone is one of the few in the Outer Carpathians, where stages of mass movement succession have been dated (Margielewski, 1994c).

ŚWINIARNIA LANDSLIDE

On the southern slope of the Hala Turbacz (Turbacz Alm) over Łomnica, a large (35 ha) – frontal, obsequent, pack-debris landslide with vast, sub-niche flattenings occurs (Fig. 1.4). The landslide has a rectilinear niche 800 m long. The lower parts of the landslide were rejuvenated by the set of niches (Fig. 4). Organic sediments consisting of a dark-brown organic silt, peaty mass, 1.8 m thick, fill up the hole on the colluvium formed during one of the rejuvenation stages (Fig. 6.5). Wood sampled from trunks found at the bottom part of the sediments in this hole was dated at 1970 ±70 yrs BP (Gd-10140). This is the date of landslide rejuvenation (Margielewski, 1994b).

WIERCH NAD KAMIENIEM LANDSLIDE

On the western slope of Mount Wierch nad Kamieniem (1082 m a.s.l.), a pack-rotary, subsequent landslide is observed (Fig. 1.5). It was initiated by the development of the valley head and the valley of the Barnowski stream (Margielewski, 1992, 1997). Rift-trenches are the main elements of this landslide. Small mass movement forms were generated in peripheric parts of the landslide during the rejuvenation period. In the colluvium of one of these forms a depression without outflow was formed. Organic sediments (peaty mass, dark organic silt) 1.6 m thick fill up the hole (Fig. 6.6). Wood sampled from subfossil trunks at the base of the sediments was dated at 770 ±100 yrs BP (Gd-6817). The date fixes the rejuvenation time of the North–West zone of the Wierch nad Kamieniem landslide (Margielewski, 1994b).

LANDSLIDES IN THE VALLEY HEAD OF THE WIERCHOMLA MAŁA STREAM

There are three dated landslide forms in the vast valley head of the Wierchomla Mała stream (a tributary of the Potaśnia stream). The valley head was strongly shaped by mass movements. These three landslides were formed in the contact zone between thick-bedded sandstones of the Magura Formation and flysch deposits of the Zarzecze Formation (Fig. 1.6–8).

Wierchomla 1 Landslide

The wide landslide zone shaped by the development of the valley head of the Wierchomla Mala stream came into being on the southern slope of Mount Lembarczek (Fig. 1.6). It is a consequent, pack-debris landslide extending from the top part of the mountain to the valley floor. It has a relatively low niche and a vast, step-shaped colluvium (Fig. 5.1). The immense depression in the sub-niche zone was formed during the main stage of mass movements. Presently, organic sediments (dark-brown organic silt and peaty mass) fill up the hole (Fig. 6.7). Wood fragments sampled from trunks stuck in the deposits give an age of 5090 ±90 yrs BP (Kr-148). The date gives the age of the main stage of mass movements forming the landslide.

Wierchomla 2 Landslide

A second landslide, situated eastwards, lower down than the one described above, is also related to the valley head of the Wierchomla Mała stream (Fig. 1.7). It is consequent, pack-debris form and has a rectilinear, high niche with vast flattering at its foot, which is blocked by a colluvial rampart (Fig. 5.2). Organic deposits (dark organic silt), 1.2 m thick, fill up the hole on the flattening. The depression was formed during the main mass movement stage (Fig. 6.8). Wood fragments sampled from subfossil trunks, which are covered with sediments, were dated at 2910 ±90 yrs BP (Kr-149). This date gives the age of the main stage of mass movements forming the Wierchomla 2 landslide.

Wierchomla 3 Landslide

An immense (35 ha) complex landslide form came into being in the eastern part of the valley head of the Wierchomla Mała stream. It is a subsequent, pack-rotary form in the upper part and the pack-debris form in the lower part (Fig. 1.8). It extends from the sub-top zone down to the valley floor. A vast, amphitheatre-like niche rejuvenated in the southern part and varied colluvium at its foot are the main elements of the described form. In the eastern and north-eastern zones, the niche is a fragment of the valley head of the Wierchomla Mała stream. It is relatively flat and high (15 m). The colluvium in the shape of elongated ramparts was transported downwards: the first of the ramparts is preserved in the sub-niche zone while the second – above the edge line of the existing valley, where colluvial swells overlapped (Fig. 5.3). Four depressions without outflow were formed between the ramparts and peat sediments fill them (Figs. 5.3, 6.9–10). The upper, wider depressions are deeper (Figs. 5.3A, 6.9). Wood fragments sampled from trunks buried in one of the upper holes yield an age of 2120 ±120 yrs BP (Gd-9412). In the lower parts of the landslide zone there are two small depressions blocked with the colluvial rampart (Fig. 5.3B). Peat deposits, 1.5 m thick, fill them up (Fig. 6.10). The beginning of sedimentation is dated at 2080 ±70 yrs BP (Gd-1176). The obtained dates describe the main stage of landslide genesis in the head valley of the Wierchomla Mała stream; they also show the relationship of both depressions without outflow to a single episode of mass movements.

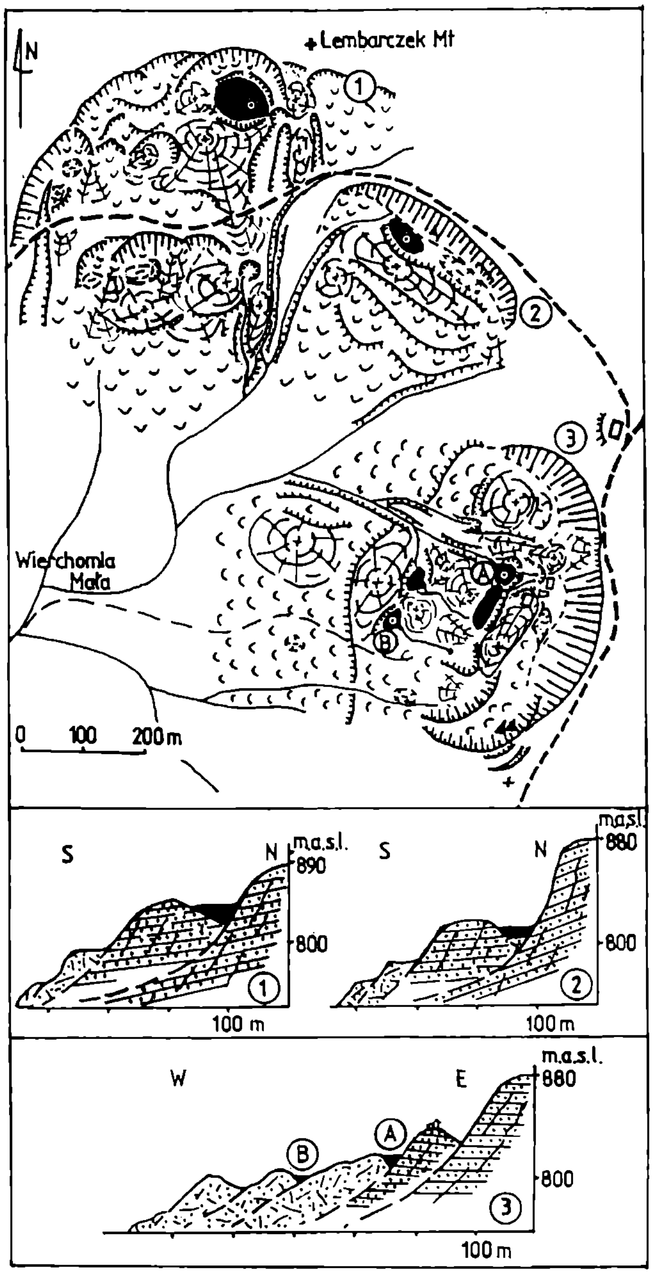

Fig. 5. Sketch and schematic cross-sections of the landslides within the valley head of the Wierchomla Mała stream: *1-3* – dated landslides (see Fig. 1.6–8), A–B – stages of landslide Wierchomla Mała 3 development. Another explanations see Fig. 2

SEDIMENTS FILLING UP THE LANDSLIDE DEPRESSIONS

In the past, all the depressions occurring in the analysed landslides were active, tub-type dew ponds characterized by the differentiated bathymetry (Fig. 6) (Nowalnicki, 1976; Margielewski, 1996). Part of them occur within the sub-niche depressions (Gaworzyna, Jesionowa, Wierchomla 1, 2), other ponds fill intercolluvial hollows (Cyrla, Wierchomla 3A, 3B, Wierch nad Kamieniem, Świniarnia).

SECTION OF SEDIMENTS

The sequence of sediments was described on the base of the core analysis. The samples of deposits were taken by a box borer. Sediments filling the depressions occur in a characteristic succession (Fig. 6). Grey-blue and blue-yellowish sandy clay with fragments of disintegrated sandstones form the bottom of the organic deposits. These are overlain by the thickest sequence of the peat sediments (peaty mass). They are represented by peats (fens type) with considerable amount of wood detritus and a homogenous, spongy, brown, sometimes sandy peaty mass with organic silt. Intercalations of wood peat and rare fragments of sandstones are also present (Fig. 6). Dark brown and dark grey, jelly like silt usually occurs at the top.

MATERIAL USED FOR RADIOCARBON ANALYSIS

At the bottom of the sediments in practically all depressions (except the Gaworzyna landslide) within the of peats or less frequently in the clays, tree trunks have been found. They probably fell down to the depressions while the landslides were formed and forests overgroving the slope were cut off. A similar phenomenon of trunk accumulation in the colluvial depression was observed when the contemporary Połoma landslide in the Bieszczady Mts formed (Margielewski, 1991). The trunks were then covered with organic sediments. Trunk deposition and mass movements took place at the same time. Therefore, the radiocarbon method of wood dating allow to fix precisely the time of landslide forming. In the case of the Jaworzyna landslides the wood samples for ^{14}C datings were picked up from the trunks covered with sediments. Only the age of the Gaworzyna landslide was obtained on the basis of wood detritus from the bottom of deposits, because the size of the depression was too small to accumulate any trunk there (Fig. 1.2). Wood detritus (wood charf) dating is less precise, but nevertheless allows to approximate the time of lanslide formation.

Single radiocarbon datings made in organic deposits filling up the depressions of the landslides in the Jaworzyna Krynicka Range do not allow an estimation of their sedimentation rate. The mean annual increase of analogous peat sediments filling up the landslide depression at Szymbark–Kamionka (Gil *et al.*, 1974) amounted to approximately 0.51 mm and the climatic changes in the Holocene caused an increase or reduction in accumulation rate (Żurek, 1986).

LANDSLIDES OF THE JAWORZYNA KRYNICKA RANGE AGAINST THE BACKGROUND OF MASS MOVEMENT STAGES DISTINGUISHED IN THE CARPATHIANS

The intensification of mass movements in the Holocene was connected with climatic changes causing increasing humidity (Gil *et al.*, 1974; Starkel, 1977; 1985, 1986, 1990; Ralska-Jasiewiczowa & Starkel, 1986, Pazdur *et al.*, 1988). During the development of the Carpathian relief in the Holocene cycle, several humid periods were distinguished. These periods recorded the stages of intense fluvial activity, increased rates of organic accumulation, and intensive mass movement development (Starkel, 1985, 1986, 1990). Humid periods are related to the termination of the Vistulian (10800–10000 yrs BP), the beginning of the climatic optimum (8500–8000 yrs BP), the middle part of the Atlantic Phase (6500–6000 yrs BP), the beginning of the Subboreal Phase (5000–4400 yrs BP) (Starkel, 1986, 1990), the termination of the Subboreal Phase (about 3000 yrs BP), the early Subatlantic Phase (2300–1800 yrs BP) (Starkel, 1990), early Middle Ages (10-th to 11-th century AD) (Starkel, 1986) and the termination of the Little Ice Age (400–100 yrs BP) (Starkel, 1986, 1990) (Fig. 7). Six stages of mass movement intensification in the Carpathians related to humid phases were distinguished by Starkel (1985), about 11000–10000, 8400–7800, 6500–6200, 5000–4700, 2400–2200, and 200–100 yrs ago (Fig. 7). There is a good correlation between the distinguished stages and the periods of intensive fluvial activity in the catchment of the upper Vistula river during its development in the Holocene (Kalicki, 1991; Krąpiec, 1992; Starkel, 1994). An increased frequency of floods related to higher humidity were recorded in the following intervals: the late Younger Dryas and the early Preboreal, 8700–7700, 6600–6000, 5200–4900, 4500–4350, 3300–2850, 2350–1650 yrs BP, 5-th to 6-th century AD, 10-th to 11-th century AD and since the 16-th century AD (Starkel, 1994) (Fig. 7).

A few humid phases and related landslide phases have been documented and partly verified by radiocarbon datings from a dozen of the Carpathian landslides (Gil *et al.*, 1974; Alexandrowicz, 1985a, 1993b). S.W. Alexandrowicz, by using datings analysis (particularly ^{14}C), distinguished 5 phases (L1–L5) of mass movement intensification (Alexandrowicz, 1993b) (Fig. 7). Palinologically dated landslides at Dziadowe Kąty (Środoń, 1952), on Mount Bryjarka near Szczawnica (Pawlikowa, 1965) and the landslide on the bank of the Skawa river valley in Wadowice (its colluvia are presently covered with sediments) (Sobolewska *et al.*, 1964) are connected with the deglaciation phase of termination of the last glaciation (11000 – 10000 yrs BP) – mass movement phase L1. The formation of some landslides (dated by geomorphological methods) in the regions of Dębica and Wieliczka (Starkel, 1960), as well as in the areas of Mount Pilsko, Lipowska and Romanka (Ziętara, 1964, 1968) was also related to the above mentioned period. At the turn of the Boreal Phase and at the very beginning of the Atlantic Phase (mass movement phase L2), the landslides at Szymbark–Kamionka and on the slope of the Parkowa Góra hill in Krynica were formed. These were dated by the radiocarbon method at 8210 ±150 yrs BP (Gil *et al.*, 1974) and 8430 ±90 yrs BP (Alexandrowicz & Alexandrowicz, 1992; Alexandrowicz, 1993b). The age of the landslide at Harcygrund near Czorsztyn was determined by the radiometric method at 7750 ±130 yrs BP (Alexandrowicz, 1984, 1993b). The main development stage of the landslide situated on the northern slope of Mount Babia Góra is also connected with

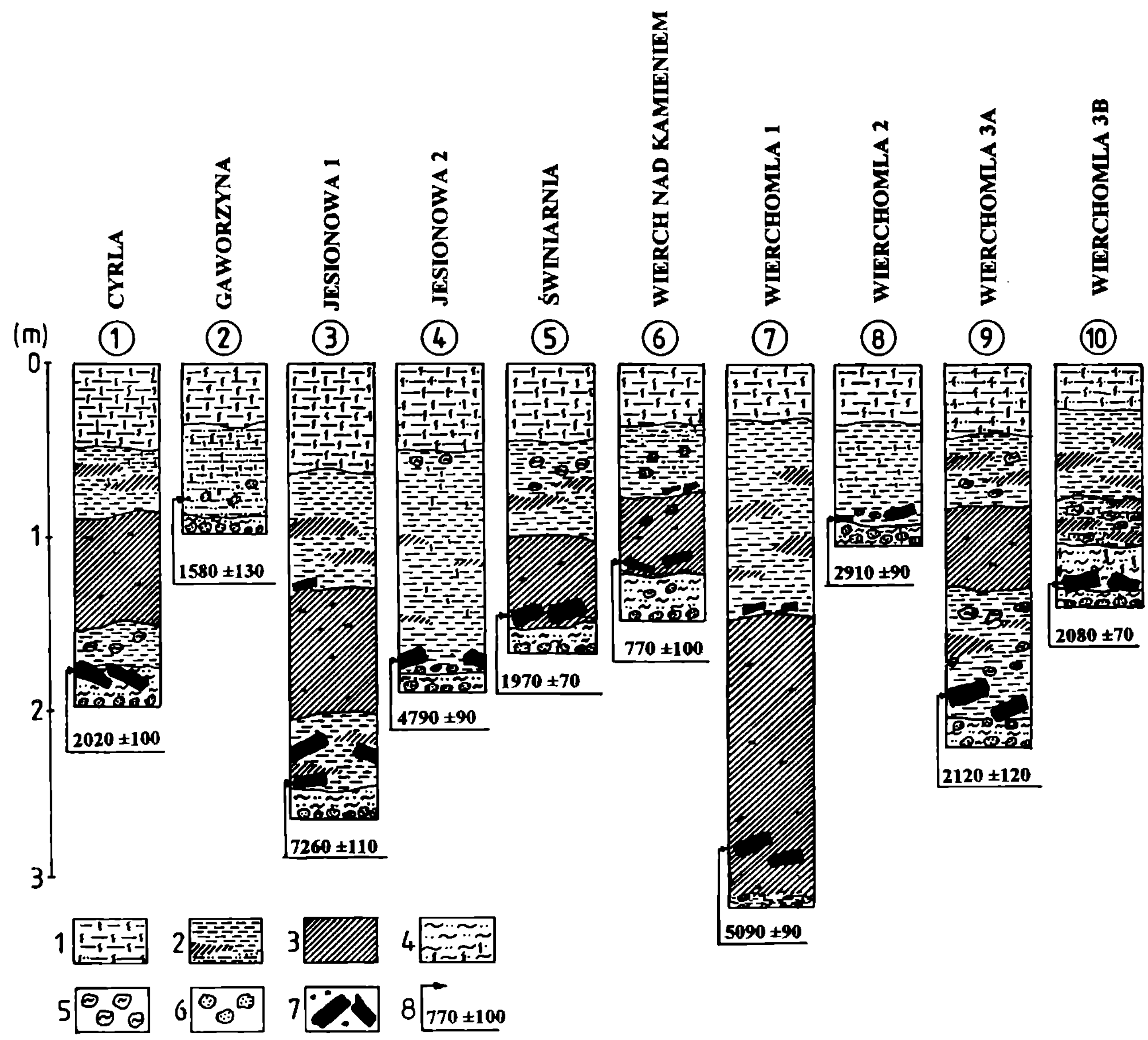

Fig. 6. Sections of organic deposits filling landslide depressions (generalized and simplified). *1* – dark organic silt with root remnants, *2-3* – peat deposits: *2* – dark and brown organic silt (peaty silt) with peat mass, *3* – peat mass mixed with wood remnants, clay and sand, *4* – yellow and brown clay with sand and fragments of sandstones, *5* – fragments of clays, *6* – fragments of sandstones, *7* – fragments of tree trunks, *8* – placement of samples for radiocarbon datings (age in yrs BP)

this phase (Alexandrowicz, 1978). The results of palinological analysis prove that sediments filling the landslide ponds are from the Middle Holocene (Trela, 1929).

The age of the landslide on Mount Cergowa in the Beskid Niski Mts was dated by palinological method as coinciding with the termination of the Atlantic Phase (Więckowski & Szczepanek, 1963).

During the humid period of the termination of the Subboreal Phase (mass movement phase L3), the landslide on the slope of the Parkowa Góra in Krynica was rejuvenated, as the date of 2690 ±110 yrs BP indicates (Alexandrowicz & Alexandrowicz, 1992; Alexandrowicz, 1993b). At the same time, the younger landslide in the Skotnicki stream valley and a small landslide form at Świątniki Górne were formed. The age of the first is 3170 ±100 yrs BP (Alexandrowicz, 1993b) and the second one is 2900 ±110 yrs BP (Alexandrowicz, 1993a). The landslide on the northern slope of Mount Palenica (Gubałówka Foothills), palinologically dated, is related to the termination of the Subboreal Phase (Harmata, 1969). The consecutive dates gained from the landslides indicate mass movement intensification in the Little Ice Age. The first period of this intensification (L4) occured in the Middle Ages. The landslide in the Biały stream valley near Krościenko dated at 535 ±30 yrs BP (Alexandrowicz, 1987, 1993b) and the older one in the Ścigocki stream valley near Krościenko aged 640 ±50 yrs BP are connected with this phase (Alexandrowicz, 1986, 1993b). During the second phase (L5) connected with the termination of the Little Ice Age (17-th to 19-th centuries), the landslide in Podolik near Piwniczna (0 ±150 yrs BP) (Alexandrowicz, 1985a), the landslide in the Kozłecki stream valley (140 ±50 yrs BP), and the younger of the landslides in the Ścigocki stream valley (250 ±40 yrs BP) were formed (Alexandrowicz, 1986, 1993b). In 1813, as a result of torrential rains, the landslide

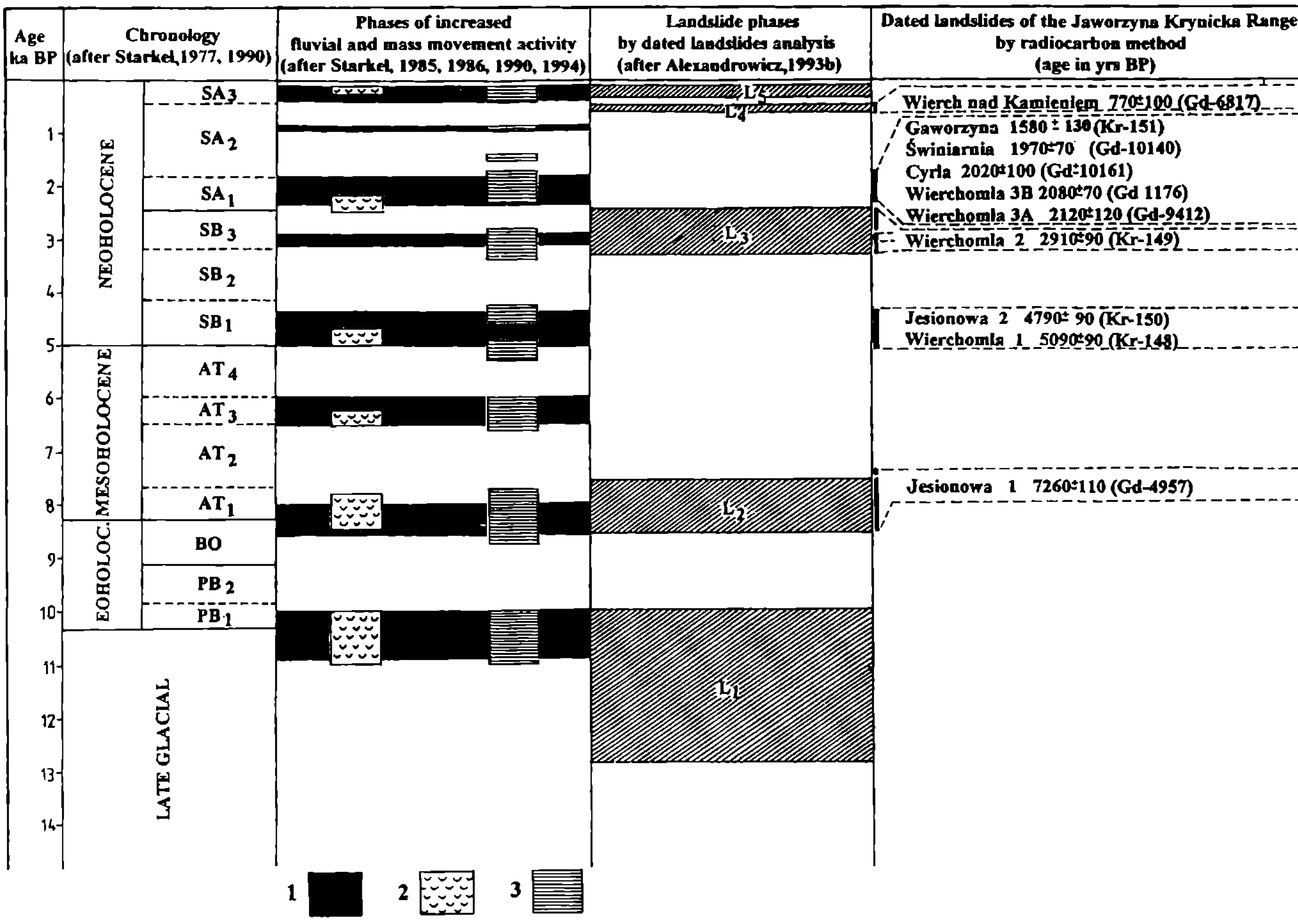

Fig. 7. Dated landslides of the Jaworzyna Krynicka Range and their link with mass movement stages in the Carpathians (after Starkel, 1985, 1986, 1990; Alexandrowicz, 1993b). *1* – main humid phases (after Starkel, 1986, 1990), *2* – landslide phases in the Carpathians (after Starkel, 1985), *3* – main phases of the higher flood frequency in the Upper Vistula Basin (after Starkel, 1994)

on the Kicarz hill near Piwniczna, was formed. The colluvium dammed up the Poprad river and a barrier lake was created (Nowalnicki, 1971, 1976).

The time of formation or rejuvenation of the dated landslides of the Jaworzyna Krynicka Range correlates with humid periods, when intensification of mass movements was recorded (Starkel, 1985, 1986, 1990) and with mass movement phases distinguished on the basis of the dated Carpathian landslides (Alexandrowicz, 1993b) (Fig. 7). The older of the landslides in the set of the Jesionowa landslide (Figs. 1.3, 3.1) is connected with late Boreal and early Atlantic Phases of mass movements Stage L2 (Alexandrowicz, 1993b) (Fig. 7). The younger landslide in the set of the Jesionowa landslide (Figs. 1.3, 3.2) and the oldest one in the valley head of the Wierchomla Mała stream (Wierchomla 1) (Figs. 1.6, 5.1) were formed during the period of mass movement intensification related to the beginning of the Subboreal Phase (Starkel, 1985) (Fig. 7). These landslides are well based in the distinguished humid phase. The second of the landslides at Wierchomla Mała (Wierchomla 2) dated at 2910 ±90 yrs BP (Figs. 1.7, 5.2) precisely coincides with the humid period in the Holocene about 3000 yrs BP (Starkel, 1990) and is placed in mass movement stage L3 (3300–2500 yrs BP) (Alexandrowicz, 1993b) (Fig. 7). Five radiocarbon datings from the landslides of the Jaworzyna Krynicka Range give good documentation of the humid phase distinguished at the beginning of the Subatlantic Phase (Starkel, 1990) in the interval of 2300–1800 yrs BP (Fig. 7). At that time, the youngest landslide in the valley head of the Wierchomla Mała stream (Wierchomla 3) (Figs. 1.8, 5.3), the Cyrla landslide near Rytro (Figs. 1.1, 2), the Świniarnia landslide (Figs. 1.4, 4) and the Gaworzyna landslide (Fig. 1.2) were formed. The first of the above mentioned landslides has two synchronous radiocarbon datings (Fig. 5.3, A–B). The youngest of the dated landslides in the Jaworzyna Krynicka Range (the Wierch nad Kamieniem landslide) (Fig. 1.5) is connected with early Middle Ages phase of humidity and coincides with radiometrically distinguished mass movement stage L4 corresponding to the older episode of the Little Ice Age (Alexandrowicz, 1993b) (Fig. 7).

CONCLUSIONS

Intensification of mass movements during the humid period during early Subatlantic Phase in the time interval of 2300–1800 yrs BP (Starkel, 1990) is well based on five datings of landslides in the Jaworzyna Krynicka Range. This allow to state that the landslide phase previously dated at

2400–2200 yrs BP (Starkel, 1985) was of longer duration: this longer period very well coincides with phase (2350–1650 yrs BP) of the high flood frequency in the upper Vistula basin (Starkel, 1994) (Fig. 7). The following two datings confirm the occurence of a landslide phase distinguished at the beginning of the Subboreal Phase (5000–4700 yrs BP) (Starkel, 1985) (Fig. 7). These landslide phases have not been documented up to now by the radiocarbon method (Alexandrowicz, 1993b). The remaining three datings widen the documentation of the landslide periods distinguished at early Atlantic Phase, at the termination of the Subboreal Phase and in the early Middle Ages (Starkel, 1985, 1986; Alexandrowicz, 1993b) (Fig. 7).

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Streszczenie

DATOWANE OSUWISKA PASMA JAWORZYNY KRYNICKIEJ (KARPATY ZEWNĘTRZNE) I ICH ZWIĄZEK Z FAZAMI KLIMATYCZNYMI HOLOCENU

Włodzimierz Margielewski

Procesy osuwiskowe odgrywały dominującą rolę w transformacji rzeźby Karpat fliszowych, zaś ich szczególna intensyfikacja była wiązana z fazami wilgotnymi holocenu (Starkel, 1985). Stosunkowo niewielka ilość datowań osuwisk karpackich, wykonanych dotychczas z użyciem metody radiowęglowej, palinologicznej, czy malakologicznej, utrudnia pełne udokumentowanie związku ruchów masowych z wydzielanymi fazami. Badania przeprowadzone w obrębie form osuwiskowych pasma Jaworzyny Krynickiej, pozwoliły na znaczne poszerzenie i uzupełnienie rejestru osuwisk datowanych radiowęglowo.

Pasmo Jaworzyny Krynickiej będące wschodnim członem Beskidu Sądeckiego, położone jest pomiędzy dolinami Kamienicy Nawojowskiej i Popradu. Geologicznie znajduje się ono w strefie występowania dwóch podjednostek tektoniczno-facjalnych płaszczowiny magurskiej: sądeckiej (bystrzyckiej) i nasuniętej na nią od południa podjednostki krynickiej. Główny grzbiet pasma wznoszący się 1000 m.n.p.m., został ukształtowany w obrębie utworów podjednostki krynickiej, reprezentowanych tu głównie przez gruboławicowe piaskowce ogniwa piaskowca z Piwnicznej formacji magurskiej oraz drobnorytmiczny flisz formacji z Zarzecza (Birkenmajer & Oszczypko, 1989) (Fig. 1). Rzeźba pasma jest silnie przekształcana licznymi osuwiskami strukturalnymi inicjowanymi głównie erozją rzeczną, zaś rozwojowi tych form sprzyja silna anizotropia tektoniczna oraz zróżnicowanie litologiczne masywu piskowcowego (Margielewski, 1997). Wśród licznych osuwisk pasma często tworzących zgrupowania, znajduje się osiem form posiadających zagłębienia (podniszowe lub interkoluwialne), współcześnie wypełnione osadami organicznymi (ciemne i ciemnobrunatne mułki organiczne i torfy) (Fig. 1). Występujące w spągowych partiach tych osadów pnie drzew, zostały powalone i zrzucone do zagłębień w czasie powstawania osuwisk (Fig. 6). Datowanie metodą radiowęglową ^{14}C materiału pobranego z tych pni w trakcie wierceń, umożliwiło stosunkowo precyzyjne określenie czasu powstania lub odmłodzenia analizowanych form osuwiskowych. W wyniku analizy radiometrycznej, osuwisko Cyrla nad Rytrem datowano na 2020 ±100 lat BP (Fig. 1.1, 2), osuwisko Gaworzyna zostało odmłodzone 1580 ±130 lat BP (Fig. 1.2) (w tym przypadku datowano jedynie detrytus drzewny pobrany ze spągowych partii osadów zagłębienia podniszowego), starsza faza osuwiska Jesionowa (Figs. 1.3, 3) była formowana 7260 ±110 lat BP, zaś młodszy etap rozwoju tego osuwiska 4790 ±90 lat BP. Fazę odmłodzenia osuwiska Świniarnia nad Łomnicą datowano na 1970 ±70 lat BP (Fig. 1.4, 4), zaś najmłodszy etap rozwoju osuwiska Wierch nad Kamieniem na 770 ±100 lat BP (Fig. 1.5). Osuwisko Wierchomla 1 powtało 5090 ±90 lat BP (Figs 1.6, 5.1), zaś pobliskie osuwisko Wierchomla 2, zostało utworzone 2910 ±90 lat BP (Figs. 1.7, 5.2). Osuwisko Wierchomla 3 (Fig. 1. 8) posiada 2 datowania: z górnego zagłębienia otrzymano datę 2120 ±120 lat BP (Fig 5.3A), zaś powstanie zagłębienia dolnego datowano na 2080 ±70 lat BP (Fig. 5.3B).

Czas powstania lub odmłodzenia tych osuwisk, jest zgodny zarówno z okresami holoceńskich zwilgoceń (Starkel, 1986, 1990) i związanymi z nimi fazami osuwiskowymi (Starkel, 1985), jak i z okresami intensyfikacji ruchów masowych, wydzielanymi w oparciu o analizę radiowęglowych datowań osuwisk karpackich (Alexandrowicz, 1993b) (Fig. 7). Intensyfikacja ruchów masowych w fazie zwilgocenia we wczesnym subatlantyku, jest w obrębie osuwisk pasma Jaworzyny dobrze udokumentowana pięcioma datowaniami (osuwiska: Gaworzyna, Świniarnia, Cyrla, dwie daty osuwiska Wierchomla 3) mieszczącymi się w przedziale 2120–1580 lat BP. Datowania te wskazują, że faza osuwiskowa wydzielana w interwale 2400–2200 lat BP (Starkel 1985) może być dłuższa, gdyż okres ten jest zgodny zarówno z zasięgiem czasowym wczesno-subatlantyckiego zwilgocenia (2300–1800 lat BP – por. Starkel, 1990), jak i z fazą wzmożonej aktywności fluwialnej górnej Wisły datowaną na 2360–1650 lat BP (Starkel, 1994) (Fig. 7). Ponadto dwie daty (młodsza faza osuwiska Jesionowa i osuwisko Wierchomla 1) dokumentują fazę osuwiskową o interwale 5000–4700 lat BP, wiązaną ze zwilgoceniem na początku subboreału (Starkel, 1985, 1986) (Fig. 7). Obydwie fazy osuwiskowe nie były dotychczas udokumentowane radiowęglowo (Alexandrowicz, 1993b) (Fig. 7). Pozostałe trzy datowania poszerzają dokumentację faz osuwiskowych wydzielanych we wczesnym okresie atlantyckim (starsza faza osuwiska Jesionowa), w schyłkowej fazie subboreału (Wierchomla 2) oraz we wczesnej fazie małej epoki lodowej (Wierch nad Kamieniem) (Starkel, 1985; Alexandrowicz, 1993b) (Fig. 7).