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LANDFORM EVOLUTION IN EUROPEAN MOUNTAINS ISBN 83-86726-96-2

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RECENT LANDSLIDES AND TRIGGERING CLIMATIC CONDITIONS IN LASKOWA AND PLEŚNA REGIONS, POLISH CARPATHIANS

Abstract. Recently, intensified landsliding was observed in the Polish Flysch Carpathians. Landslides of 1997 and 2000 are examined using examples of Laskowa and Pleśna, two regions located in the middle and eastern part of the Flysch Carpathians yet in different geological settings (flysch complexes, loess-like deposits, Quaternary covers). It has been stated that in both the discussed regions weather conditions were the dominant triggering factors as the mass movements referred to various landslide types (subsequent, consequent, complex). Moreover, it has been evidenced that in year 2000 the factors conditioning the development of landslides were sequences of snowfalls followed by thawing, in opposite to year 1997 when the instrumental factor was an overlapping of the local storm downpours with continuous rainfall.

Key words: landslides, climatic triggers, Flysch Carpathians

INTRODUCTION

Landslides are common and serious problem in mountainous regions of many countries. The Polish Carpathians and their foreland are not an exception here and represent an ecosystem in which critical damages are caused, apart from floods, just by landslides. Although the Polish Flysch Carpathians amount only to 6% of the country area, over 90% of all forms of mass movements recorded in Poland concentrate on mountain slopes and river valley sides of this region.

Landslides belong to natural hazards that are results of conjunction of several factors, traditionally called determining (or passive) and triggering (or active) causes. The determining causes are geology, morphometry, hydrology, land-use etc., while triggering causes are meteorological and seismic events. All these factors make the Polish Carpathians prone to landsliding as evidenced by a broad literature (Zuber and Blauth 1907; Łoziński 1909; Sawicki 1917; Świderski 1932; Teisseyre 1936; Kleczkowski 1955; Gerlach et al. 1958; Bargielewicz

1961; Boretti-Szumańska 1960; Michalik 1962; Ziętara 1964, 1974, 1988; Bober 1979, 1984; Dauksza and Kotarba 1973; Gil and Kotarba 1977; Dziuban 1983; Kotarba 1986; Margielewski 1991; Starkel 1960).

Effects of landslide hazards are twofold. First, the resulting re-modelling of slopes is very spectacular and clearly visible in the relief. Second, landsliding causes damage to farmland, households, infrastructure and in extreme cases — casualties. Unfortunately, landslides are often underestimated or even neglected as their recurrence intervals can vary from a few to hundred or even thousand years.

Very spectacular landsliding in the Polish Flysch Carpathians was observed recently in the period between summer of 1997 and spring of 2000. The performed field examination has shown that apart from environmental vulnerability associated with geological structures, lithology, morphology and land-use, climatic factors are the triggers of landsliding in these particular cases. Landsliding events were widespread in the Carpathians, yet their concentration corresponds well to the regions of high precipitation. The landslides that had been activated in July of 1997 caused disturbance of formerly stable slopes. Activating and renewal of landsliding events was also observed in 1998, 1999 and in spring of 2000 when specific weather condition of winter season and spring precipitation brought about landsliding comparable with that of July 1997.

SCOPE AND PURPOSE OF STUDY

The scope of the paper is limited to the area of landslides activated or re-juvenated in Laskowa and Pleśna regions, two gminas* located in the Beskid Wyspowy and Rożnów Foothills, respectively (Fig. 1).

The aim of the paper is to show a specific role of climatic factors, mainly precipitation as the landslide triggers. Meteorological records of IMGW stations located in Limanowa, Rozdziele, Tarnów and Wojnicz, being the closest located to the discussed gminas, are analysed (Fig. 1). The emphasis is on two specific situations: storm precipitation of summer 1997 and precipitation combined with thawing of 1999/2000 winter season.

BRIEF OVERVIEW OF PASSIVE FACTORS

Major features of the Outer Carpathians are thick flysch complexes (alternated porous sandstones, conglomerates, claystones, mudstones and shales), folded and thrust-faulted structures, complicated orientation pattern

* Term gmina denotes the smallest administrative unit of Poland and is used throughout this paper following the convention accepted by US EPA for local administrative nomenclature.

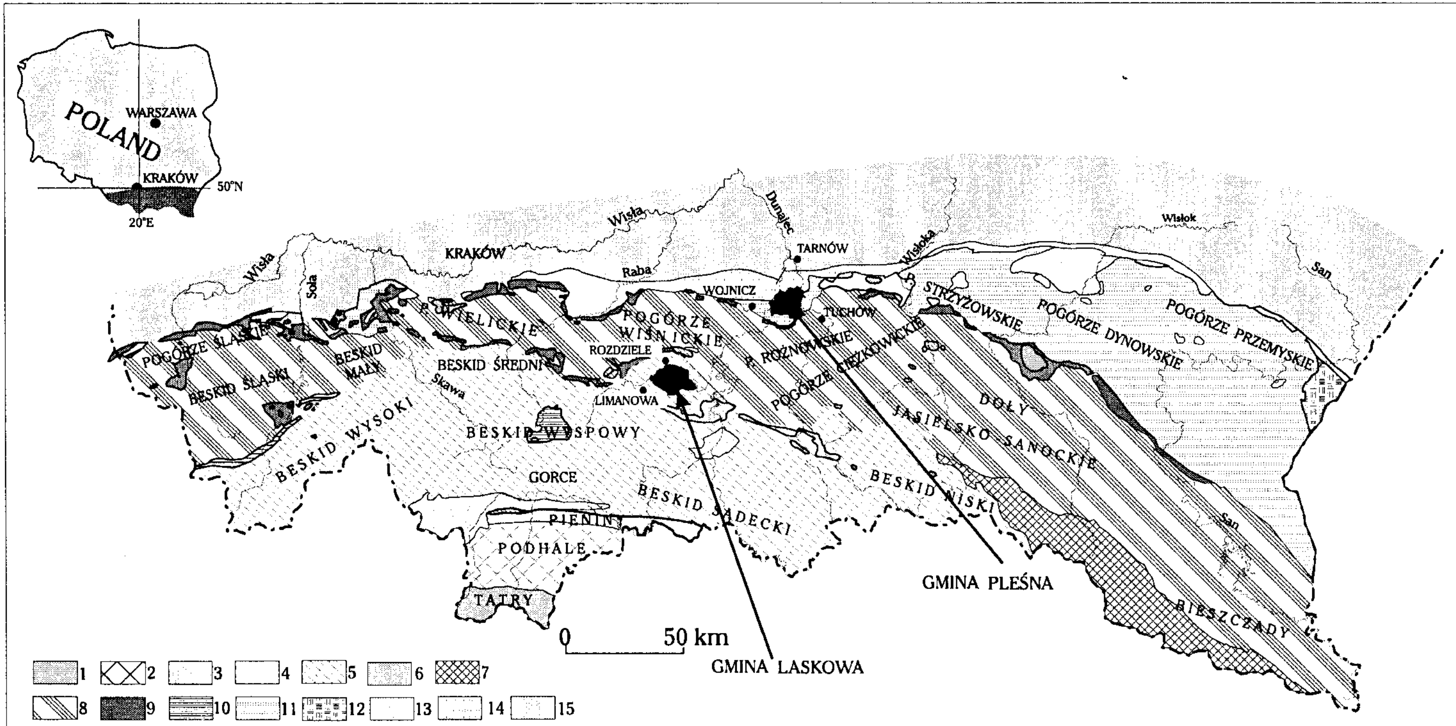

Fig. 1. Location of study areas, meteorological stations, major geological units and geomorphologic regions of the Polish Carpathians. 1 — Tatra units, 2 — Podhale flysch, 3 — Pieniny Klippen Belt, 4 — Neogene deposits of Orawa–Nowy Targ Basin and Nowy Sącz Basin, 5 — Magura Unit, 6 — Pre-Magura (Grybów) Unit, 7 — Dukla Unit, 8 — Silesian Unit, 9 — Subsilesian Unit, 10 — Dukla and Grybów units of Mszana Dolna tectonic window, 11 — Skole Unit, 12 — Stebnik Unit, 13 — patches of Miocene sediments on flysch deposits, 14 — Neogene and flysch deposits folded together, 15 — Neogene deposits of the Carpathian foredeep

of beds and strata. The Carpathian Foothills are also built of flysch series, but are less resistant to erosion (Kotarba 1989). The flysch is often mantled with weathered material forming slope covers (clays, loams, silty sands and debris) which are more or less permeable depending on grain size composition. Thick permeable fluvial deposits and often loess-like sediments occur in intra-mountain basins and at the Carpathian fringe. L. Bober (1984) showing a spatial layout of landslides, emphasises their close relationship with lithofacial development of the Carpathian flysch.

Gminas of Laskowa and Pleśna match well the general geological setting described above (Fig. 1). Gmina Laskowa is located within the zone of the Magura unit (Burtan and Skoczylas-Ciszewska 1966). The Łososina valley, forming the central part of the gmina, is incised in Oligocene-Eocene shales with sandstone inserts that belong to the sub-Magura beds. From tectonic point of view it is a local zone of the Laskowa anticline. The latter is built of sandstones belonging to sub-Magura beds. The Laskowa anticline runs south of the Laskowa Górna–Kamionka Mała anticline built of variegated shales of the Magura unit. The zone of sub-Magura beds is characterised by numerous larger and smaller slices. The anticline zone where variegated shales occur and its eastward extension being a zone of fine rhythmical, mainly shale flysch make this area particularly landslide vulnerable.

On the other hand, gmina Pleśna is located in the region of the Skole unit deposits and in the zone where these deposits are thrust over the Miocene of the Carpathian Foredeep. Major rocks occurring in this gmina are: shale-marl-sandstone complexes, fine and medium sandstones as well as thick-bedded sandstones and shales and deposits of Inoceramus beds. They are overlain by several meter thick covers of loess-loams and loess-like deposits. Characteristic features are strong tectonic deformations (Wdowiarz 1951). In the valley bottoms there are deposits of Holocene and Pleistocene river terraces. Deep structural landslides occur in the overlying covers and in the substratum as well.

From morphological point of view the discussed gminas occupy regions belonging to two different geomorphic units. Gmina Laskowa is in the north-eastern part of the Beskid Wyspowy Mts, namely between Kamienna and Jaworz Ridges while gmina Pleśna is in a central part of the Carpathian Foothills, in the Płaskowyż Wału (Wał Plateau) belonging to the Pogórze Wiśnickie (Wiśnicz Foothills).

Relief in gmina Laskowa generally corresponds with tectonic and lithologic features. Summits of Szałasz (909 m a.s.l.), Jaworz (917.9 m a.s.l.) in the south and Kamionna (801.3 m a.s.l.) in north-western parts of the gmina are the highest spots. Slope inclinations vary from 20° to 30° and numerous hills are often isolated forms, separated by deeply incised stream valleys, so height differences are 400–580 metres. The major river Łososina flows eastward and bisects the territory into the northern and southern parts.

A series of relatively narrow, almost rectilinear valleys of the northern part and almost perpendicular to the Łososina river and drained by its tributaries, are characterised by high slope gradients which make them the areas of high landslide potential. Valleys of the southern part are also rather straight and arranged in similar pattern.

In gmina Pleśna absolute elevations slightly exceed 500 m a.s.l. (summit of Wał — 523.3 m a.s.l.) and slope inclinations vary from 15° to 25°. The differences in relative heights are of the order of 200–300 m. The major river of this gmina is the Dunajec flowing in the western fringe while its other parts are drained by the Biała Dunajcowa and other smaller streams which do not show a regular pattern. However, the spatial distribution of landforms (hills, valleys, incisions, headwaters etc.) affects scattered layout of landslides here.

Both the gminas are typical rural areas with tiny farmland lots located, for example even as high as 400–480 m a.s.l. in Poddziele or Laskowa Górna and 350–400 m a.s.l. in Rychwałd. Cultivation of cereals and root plants only rarely gives way to orchards and meadows. Therefore, disadvantageous layout of grassland and arable fields is water flow accelerating, soil erosion promoting and, in extreme cases, earthflow contributing.

Location of dwellings is often inadequate, especially if the setup of new buildings is associated with overloading of uphill sections and destabilisation of a slope equilibrium. As dwelling outgrowth continues to expand onto the steeply inclined terrain more and more areas are under increased landslide risk.

CLIMATIC TRIGGERS OF LANDSLIDES

A brief outline of meteorological conditions, presented below, provides a background for demonstrating a causal relationship between precipitation and snowmelt triggers and landsliding in the discussed regions.

In summer of 1997 catastrophic precipitation was associated with development of an almost stationary low pressure system that had persisted over south-eastern Poland and western Ukraine for 6 days, from 5 to 8 July (Niedźwiedź and Czekierda 1998). The analyses of weather conditions presented by T. Niedźwiedź and D. Czekierda (1998) and T. Niedźwiedź (1999) indicate that the highest precipitation was recorded first in the Beskid Śląski Mts, and then in the Beskid Sądecki Mts., Beskid Wyspowy Mts, and the Tatras due to small shifts of this low pressure system. Although on 9 July the low pressure system started to shift eastward and precipitation was ceasing in the western part of the Carpathians, a catastrophic downpours occurred this day in the late afternoon and evening. On 9 July recorded precipitation intensity were as high as 122 mm per 2 hours in Rozdziele and 40 mm per hour in Limanowa (Niedźwiedź et al. 1999). Between 10–17 July there was a period of fair weather. Unfortunately, a new low pressure system developed on 18–20 July and initiated another series of rainfalls and, again storms affected south-eastern Poland. As reported by T. Niedźwiedź and D. Czekierda (1998) the downpour that developed over city of Tarnów on 19 July was very heavy and amounted to 43 mm in 57 minutes. Similar scenarios were the cases of many sites located in the Pogórze Wiśnickie, Pogórze Rożnowskie and Pogórze Ciężkowickie (central part of the Carpathian foothills). The high daily precipitation of July were recorded not farther east than Dunajec drainage basin. Their spatial extent delimits the spatial extent of landslide phenomena which were registered in this period. These enormous daily precipitation added up to very high monthly totals exceeding 300 mm in Rozdziele and Limanowa or 240 mm in Tarnów and Wojnicz. There is a good agreement between these high monthly precipitation totals and landslides that were registered as active in July 1997 (Fig. 2).

The storm induced downpours were particularly detrimental, as the antecedent rain contributed to water saturation of the ground. In 1997 precipitation totals in Limanowa and Rozdziele reached 139 mm and 141 mm in May (these values exceeded monthly means of the multiannual period of 1951–1996 — Niedźwiedź et al. 1999) and 70 and 81 mm in June, respectively. Landsliding

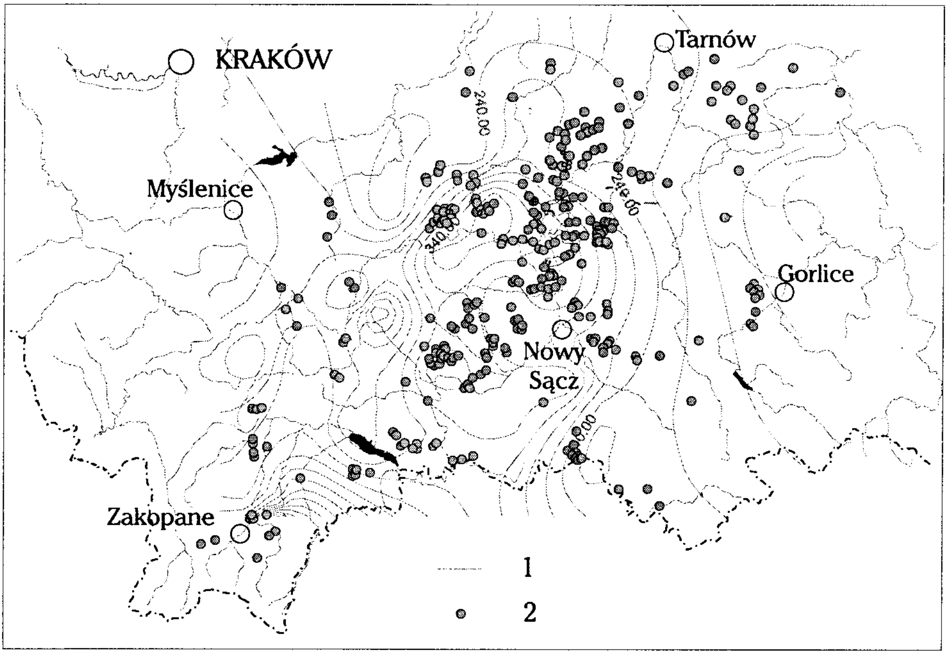

Fig. 2. Monthly precipitation in July 1997 and distribution of active landslides in the middle part of the Polish Carpathians. 1 — precipitation isolines, 2 — active landslides

movements in this area are reported of 7 to 9 July. In some localities, however, another minor landsliding was registered about 10–12 days later (e.g. Kamionka Mała, Żmiąca) in relation to the next storm event of 18–20 July.

In the central parts of the Carpathian foothills cumulatitive rainfall preceding catastrophic storm events was lower. In Tarnów, for example, monthly precipitation totals of June and July 1997 do not exceed the corresponding multiannual values. However, the storm induced downpours of July 1997 were also extreme and triggered mass movements. The field inventory of landsliding events confirms their coincidence with tremendous storm of 19–20 July in the Dunajec drainage basin.

In the following two years 1998 and 1999 the annual rainfall actually exceeded the multinannual values but monthly totals were generally lower than July precipitation of 1997. Mass movements, if occurred were confined to singular localities and did not show a catastrophic character.

The situation was completely different in spring of 2000, when another dramatic activation of mass movements was recorded in April. The number of incidences and spatial extent of landsliding is comparable with that of 1997. The major triggers in the case of both the discussed gminas of Laskowa and Pleśna are specific weather conditions. Precipitation totals and thickness of snow cover, as illustrated in Figure 3, point to a rather mild winter season. Although the snow cover was observed from November till March it disappeared several times during the season. However, it was often as thick as 40–50 cm in Limanowa or Rozdziele, and only 20–30 cm thick in Wojnicz and Tarnów.

Continuous periods of mean or minimum air temperature below freezing lasted of an order of decades (30 days maximum) and were separated by intervals of positive temperatures with extreme values reaching even +7.6°C and +14°C in January and February in Limanowa or +6.2°C and +15°C in Tarnów, respectively. The positive temperatures contributed to thawing of the snow cover in the mid-winter season and, therefore, meltwater could easily have percolated into unfrozen substratum. This way conditions favouring instability had developed. Precipitation of 5 April was the highest recorded this winter and amounted to: 51.8 mm — in Limanowa, 41.2 mm — in Rozdziele, 40.6 mm — in Tarnów, 47.3 mm — in Wojnicz (Fig. 3). On the same day cold front moved over this regions and as it had passed, the snow falls were recorded again. These specific weather conditions became triggers of landsliding phenomena observed in a lag of a couple days when the snow had melted.

LANDSLIDING EVENTS OF 1997 AND 2000

After the catastrophic rainfall of July 1997 the Carpathian Branch of the Polish Geological Institute was in charge of a field inventory of mass movements in the central part of the Polish Carpathians. Over 500 landslide

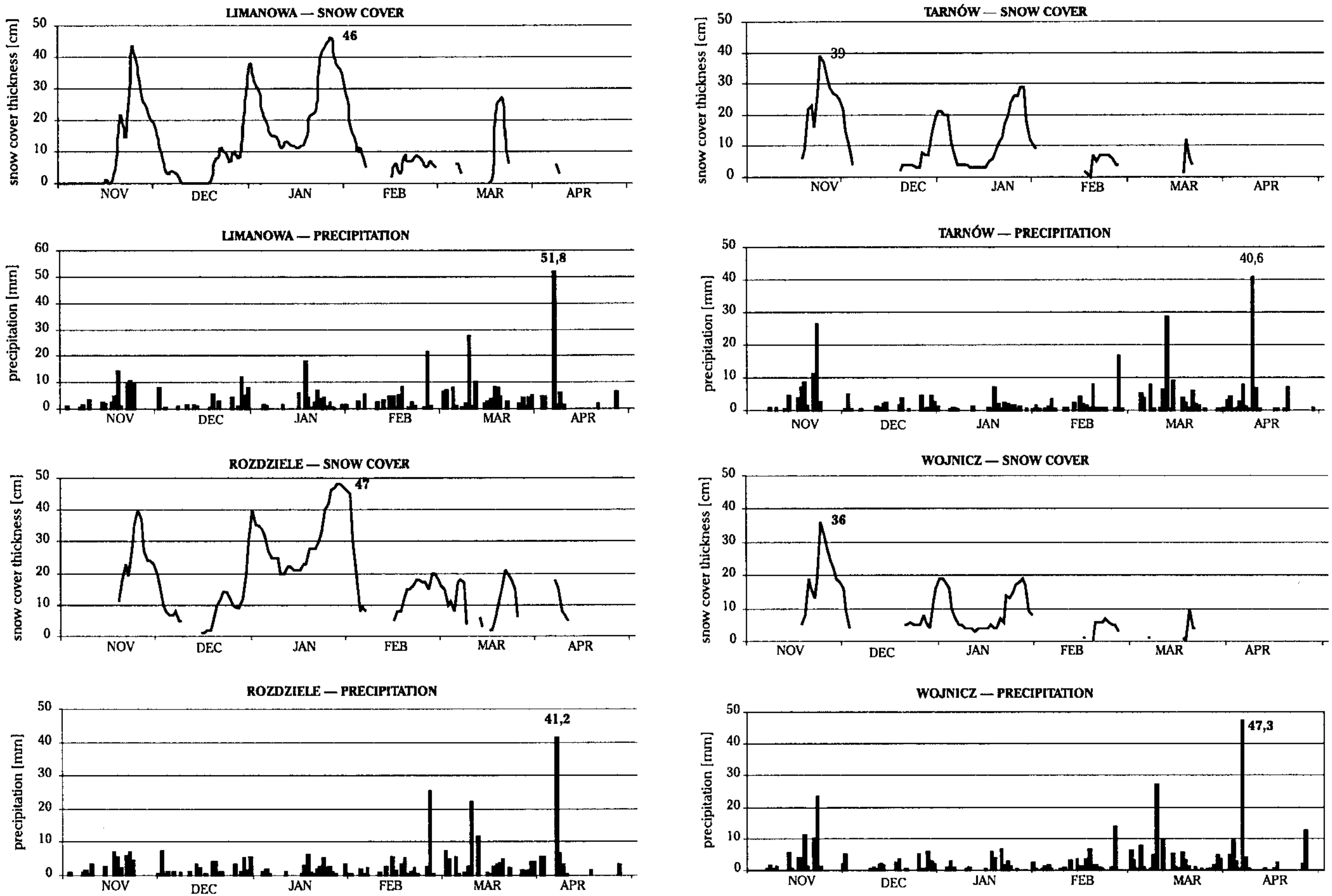

Fig. 3 Precipitation and thickness of snow cover in winter season 1999/2000 in Limanowa, Rozdziele, Tarnów, Wojnicz

forms have been enumerated during this inventory task. The areas occupied by a newly developed forms or rejuvenated ones vary from a few to over 100 ha each. The landslides occurred on various lithological flysch members and in the Quaternary deposits. The weathering covers were displaced by shallow landslides while deep structural landslides transferred huge packets of flysch together with Quaternary covers. In places the overlying material was completely removed so the bedrock was exposed (e.g. rigid sandstones). Under the framework of this inventory task gminas of Laskowa and Pleśna were examined. Distribution of major landsliding events of this period is shown in Figure 4 (marked by dots).

Another inventory work was undertaken in April 2000 as a response to the demand of local authorities of gminas Laskowa and Pleśna strongly affected by landsliding. The results of the survey of this period are also shown in Figure 4 (marked by asterisks) for the sake of comparison.

LANDSLIDING IN GMINA LASKOWA

As it has been stressed already, the first series of landsliding events in gmina Laskowa is associated with the catastrophic summer precipitation of 1997. Various forms of mass movements including sliding, creeping debris flows etc. were observed on the hill slopes and valley sides. Major recorded phenomena occurred north of the Łososina river, in regions of villages Laskowa, Laskowa Górna, Krosna and Kamionka Mała (Fig. 4A — dots). South of the Łososina river less landsliding events were enumerated. Here, they concentrated mainly in a region of Żmiąca village and in summit parts of Jaworz as shown by T. Ziętara (1998, 1999). Geomorphic evidences of the mass movement are newly exposed niches, undulated and bulged terrain indicating landslide tracks and 100–250 cm thick heaps of material deposited in frontal parts (Photo 1). Unfortunately, the rate of movement can be only estimated indirectly and according to members of local communities their households and lots were covered with a down-moving material within 1–2 hours. The tragic detrimental effect was the damage of housing in Kamionka Mała (Fig. 4A — sites 23–25, dots) and even one toll for life (Poprawa and Rączkowski 1998, 1999).

The landslide phenomena of spring 2000 affected some former localities that were active in 1997 as well as new ones. A good example of the locality subjected to mass movements in both the discussed periods is the landslide on the north-facing slopes of Jabłoniec hill (Fig 4A — sites 8–14, dots and site 1, asterisk). Major changes in morphology of the hill are depicted in Figure 5. A new scar formed in the landslide niche in 1997 (Photo 2) and resulted in bulging of downward located farmland. Major transportation tracks were on the western fringe of the landslide and the moved material caused real hazard to houses located in the middle part of the slope (Fig. 5). The movement manifested also in the landslide front where it was clearly evidenced by fissures on houses (some of the houses became unsafe for dwelling).

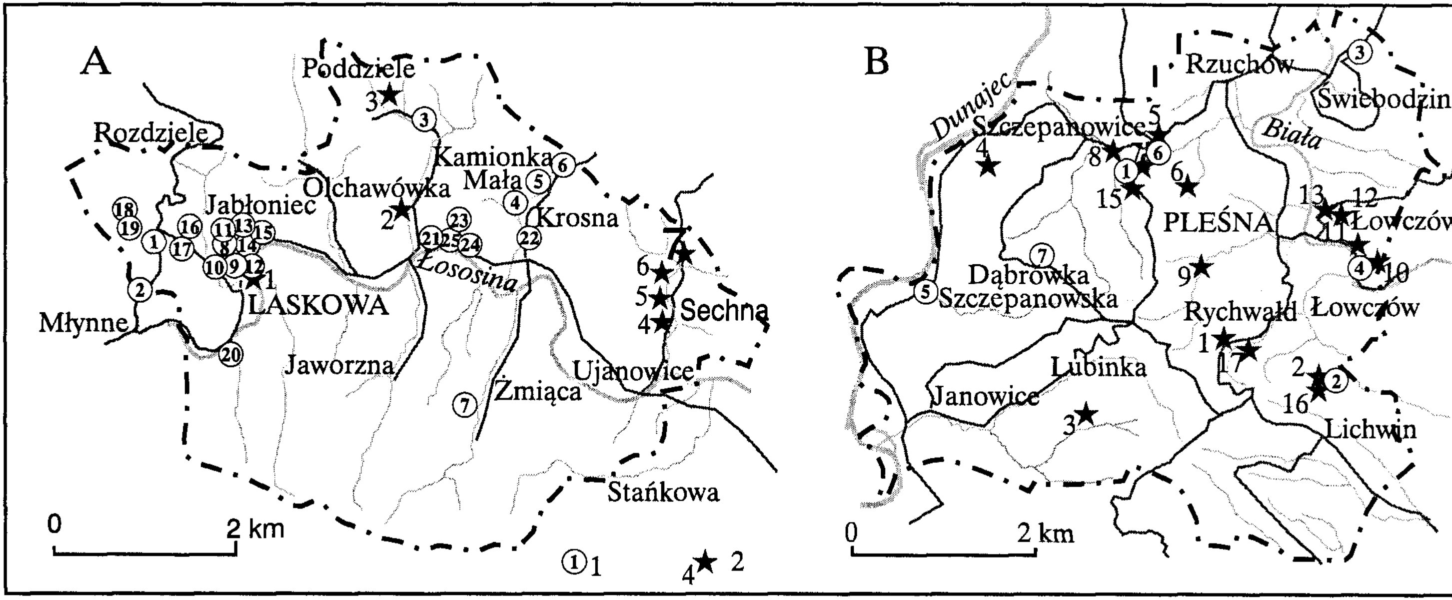

Fig. 4. Location of active landslides in gmina Laskowa and Pleśna. 1 — landslides active in July 1997, 2 — landslides active in April 2000

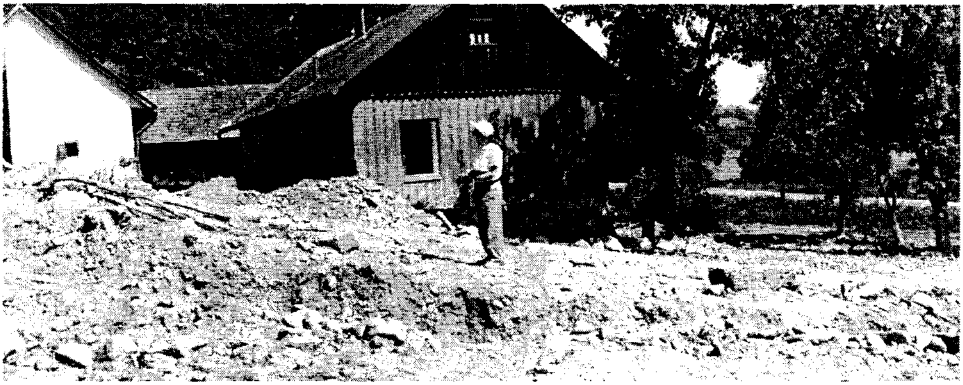

Photo 1. Debris rampart in a frontal part of landslide in Laskowa (August 1997)

Photo 2. Scar and earthflow in the landslide niche on Jabłoniec hill (12 April 2000)

In 2000 movement was observed mainly in the front of the landslide (Fig. 5 — arrow pointing to the scar at edge of the regional road Młynne–Ujanowice and a year given in parenthesis). Here, a dramatic effect is the damage of the road whose one lane had been thrown down by 80 cm (Photo 3). The discussed movement is attributed to a combined action of Łososina undercutting and unfavourable water conditions uphill, resulting from saturation of the slope covers during the winter season of 1999/2000 (as explained above). Snow fall related to the cold front after 5 April was

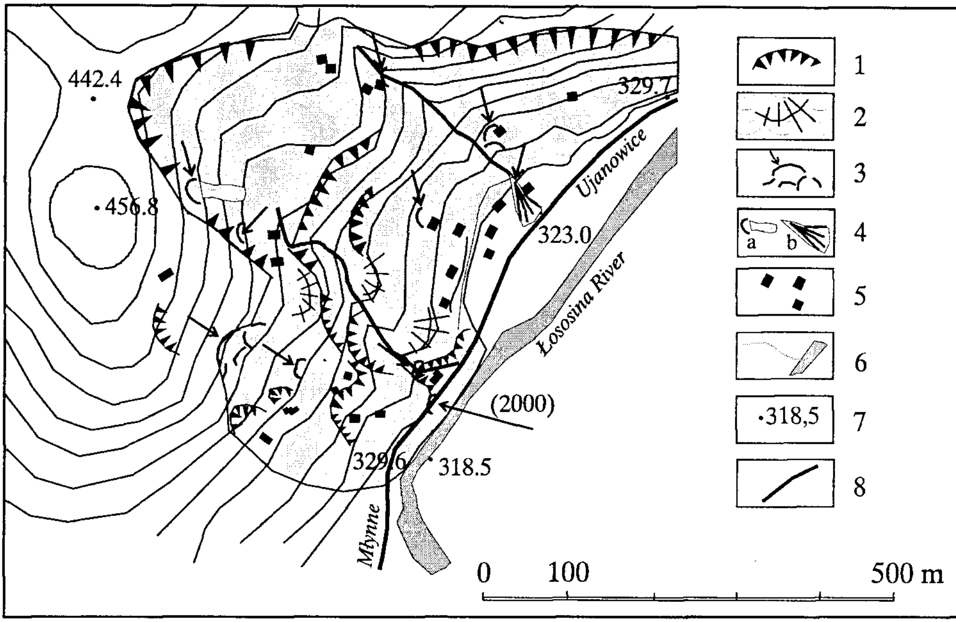

Fig. 5. Landslide on the slope of Jabłoniec hill near Laskowa village. 1 — old niches, 2 — mounds and bulges of displaced colluvium, 3 — niches and cracks developed after precipitation of July 1997 (in 2000), 4: a — scars and earth flow of 1997, b — debris flow generated heap, 5 — endangered houses and buildings, 6 — river and streams, 7 — elevation a.s.l., 8 — paved road; arrows show directions of displacement

the final trigger. The movement inferred from a width of expanding cracks in the pavement of the road was still observed between 12 and 19 April 2000. The upper and middle parts of the landslide remained rather stable at this time as fresh scars, swellings or other morphometric changes were not observed during the spring fieldwork.

Olchawówka landslide represents the form which was dormant in 1997 and active in spring of 2000 (Fig. 4A — site 2, asterisk). A newly developed niche has a 2 m high main scarp. The main body features numerous deep, transverse cracks and fissures (Fig. 6). The displaced material moved along several tracks, so at least two major toes can be distinguished: one stopped in the vicinity of the junction of Kamionka stream and its tiny tributary, the other just terminated at the right bank of the Olchawówka stream itself, almost above the exposure of variegated shales (Fig. 6, Photo 4).

Severe landsliding took place in the Sechna stream valley. Numerous, scars are observed on the hills sloping towards the both banks of the stream and bulging of the road Ujanowice–Dobrociesz is a typical, repeatable outcome of mass movements here (Fig. 4A — sites 4–7, asterisks). The landslide developed in the middle part of the valley on the south-east facing slopes

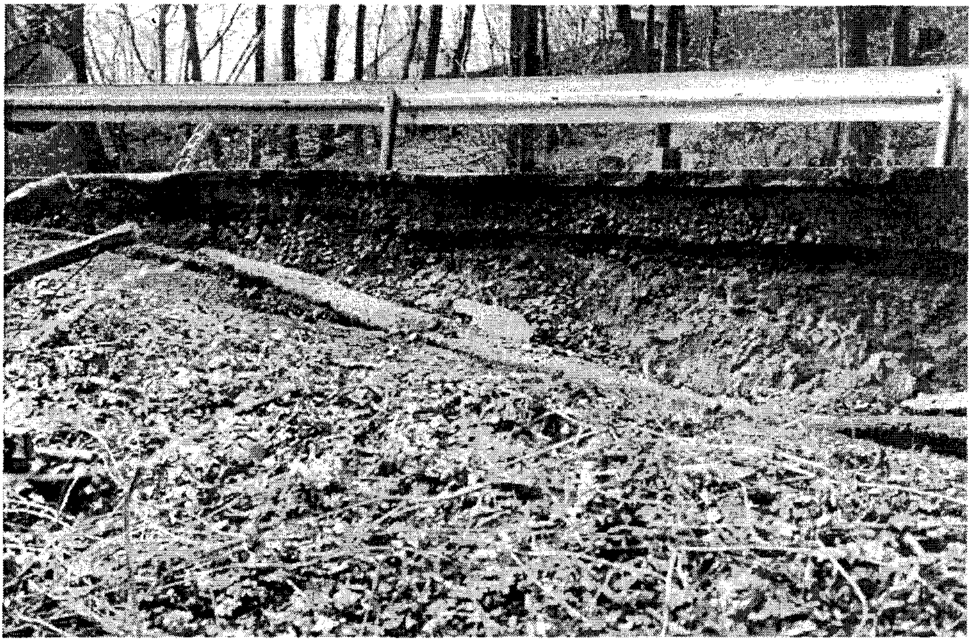

Photo 3. Thrown down lane of the Młynne–Ujanowice road in the frontal part of Jabłoniec landslide (12 April 2000)

Photo 4. Lobes and cracks of the landslide on Olchawówka hill (12 April 2000)

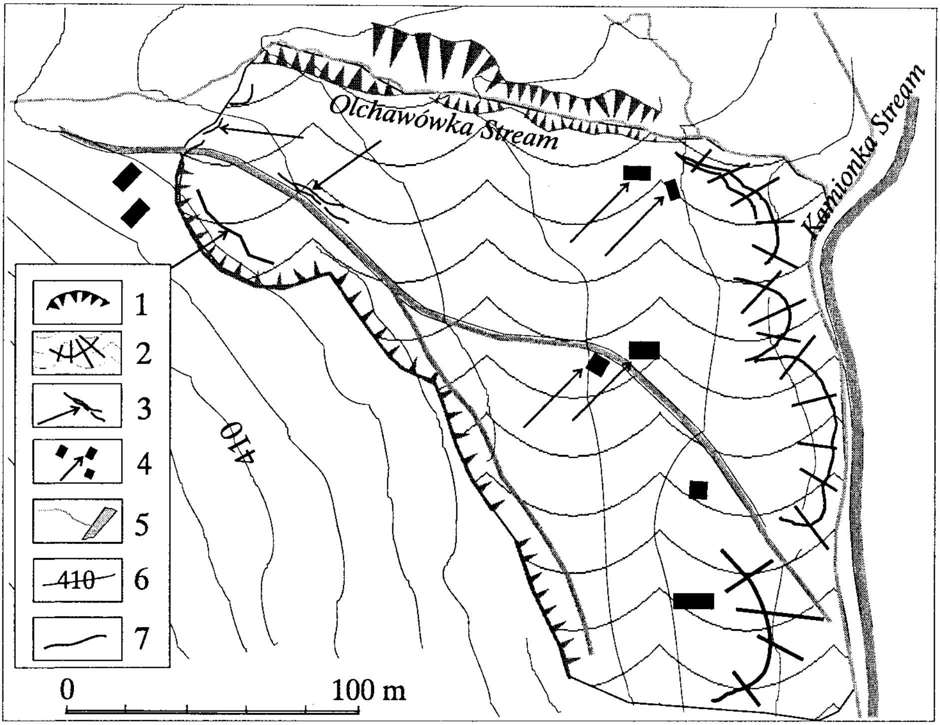

Fig. 6. Landslide on the slope of Olchawówka hill. 1 — old niche, 2 — mounds and bulges of displaced colluvium, 3 — niches and cracks developed in 2000, 4 — endangered houses and buildings, 5 — streams, 6 — elevation a.s.l., 7 — local paved roads; arrows show directions of displacement

of Gwizdówka hill (Fig. 4A — site 6, asterisk) focuses special attention. It was active in summer of 1997, yet much larger displacement was observed in spring of 2000. The outline of the landslide is shown in Photo 5. The downslope displacement of material in the main body is about 1.2 m per year to 3.6 m per 2 years. This landslide is particularly hazardous as its continuing movement might lead to damming of the Sechna stream, and then, the inundation of downward localities is a likely scenario.

LANDSLIDING IN GMINA PLEŚNA

Spatial layout of mass movements of July 1997 and April 2000 in gmina Pleśna is shown in Fig. 4B. As evidenced by the fieldwork, landsliding of 1997 manifested in a re-juvenation of old (Pleistocene and Holocene) forms and in formation of new ones mainly in Szczepanowice, Dąbrówka Szczepanowska, Łowczówek, and Lichwin on slopes with and without loess-like covers. The field examination performed in spring of 2000 indicates that this time mass movements (including sliding, slumping, flowing etc.) were even more intensive and more incidences were recorded (Fig. 4B — asterisks). Photo 6 presents

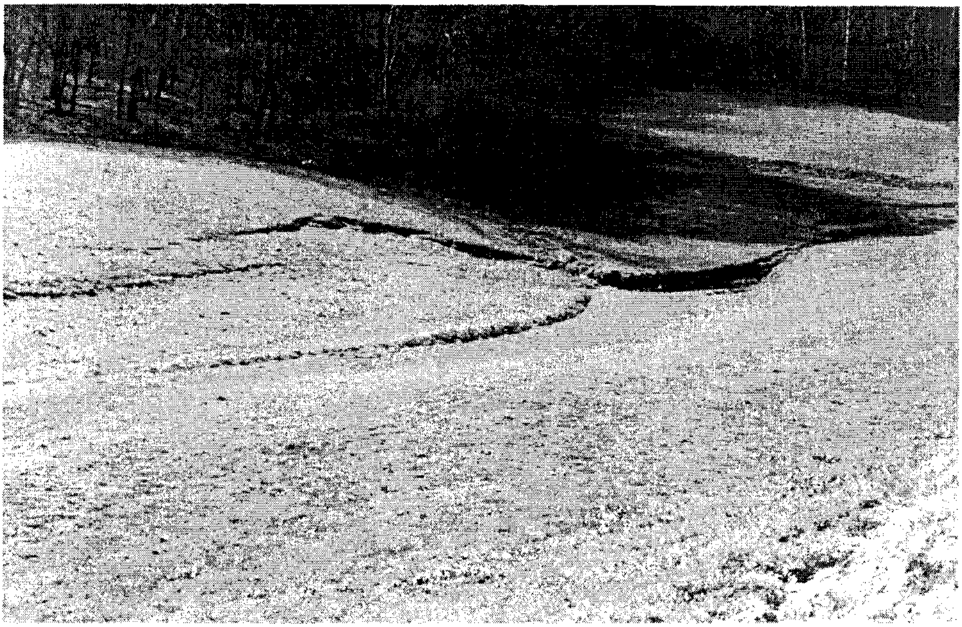

Photo 5. Niche and cracks outlining the landslide in the Sechna valley (12 April 2000)

the slope in Rychwałd with fresh landslide features which came into being just in April 2000. In opposite to the situation of 1997, in numerous cases new niches with steep scarps and displacements occurred both within the old niches as well as on the main bodies and toes of the landslides (e.g. in Łowczówek). It was especially the case of the forms developed where thick loess cover occur and is a good evidence of importance of passive factors.

The undergoing processes and resultant effects might be well illustrated by the changes observed in the landslide in Szczepanowice (Fig. 7) whose crone is adjacent to the road Rzuchowa–Lichwin. This landslide is active and its continual movement is monitored by road conservation services. Cracks, fissures and material displacement of 1997 are minor changes when compared with spectacular forms of 2000. The renewed niche has an over 5 m high exposed scarp, deep and numerous cracks indicate often secondary fractures, water ponds occupy the undulated and bulged middle part (Photo 7). The toe is also deformed in a complex way and its overriding resulted in damage of houses located at the landslide side.

The landslide developed in Szczepanowice (Fig. 4B — site 8, asterisk) is another instance where geological settings and morphological conditioning were less important and subdue to the triggering meteorological causes. The present form of this landslide has developed in the response to weather conditions in the preceding months and the snow fall of April 2000. Huge slabs, not only of arable soil layer but also of underlying covers, slid or slumped about

Photo 6. Landslide slope in Rychwałd, gmina Pleśna (17 April 2000)

Photo 7. Landslide in Szczepanowice, gmina Pleśna (17 April 2000)

80 cm down marking an arcuate outline at the head of this landslide. Secondary cracks and swamps (sometimes with water table at the ground surface) are other characteristic features of this landslide. Although activation of this form

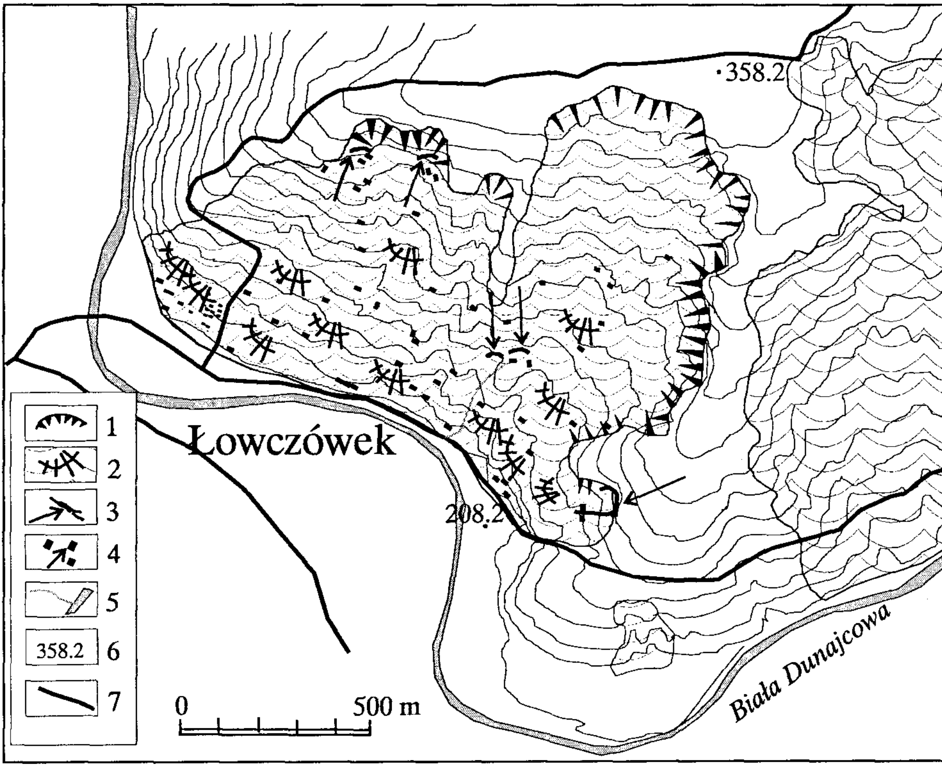

Fig. 7. Landslides on the south-facing slopes in Łowczówek village in gmina Pleśna explanations as in Figure 5. 1 — old niches, 2 — mounds and bulges of displaced colluvium, 3 — niches and cracks developed in 2000, 4 — endangered houses and buildings, 5 — river and streams, 6 — elevation a.s.l., 7 — local paved roads; arrows show directions of displacement

resulted mainly in degrading of the farmland, its progressing movement is hazardous for houses located downslope.

An overview of the landslides discussed above is summarised in Table 1.

DISCUSSION AND FINAL REMARKS

The relation between the intensity and duration of precipitation as the major relief transforming factor, has been subject to extensive examination. L. Starkel (1976) has worked out rainfall typology with a subdivision into the local short-lasting downpours, continuous rainfalls and rainfall seasons as well as periods of rapid melting of a snow cover. Later, studies on the response of slope process and channel systems to various types of rainfalls (Gil and Kotarba 1977; Gil and Starkel 1979; Starkel 1979, 1980; Froehlich and Starkel 1991, 1995; Gil 1994, 1996) resulted in determination of precipita-

Table 1

Landsliding in gmina Laskowa and Pleśna

Region	Landslide	Geology	Landslide type according to L. Bober (1984)	Activity and features	
				1997	2000
Gmina Laskowa	Jabłoniec sites 8–14, dots site 1, asterisk	Sub-Magura Beds	Complex	**active;** movement of the entire form: new niches, earth flow, bulding in the body and pushing by the toe	**active;** fragmentary movement — head part — dormant fresh scar, pushing and movement at the toe
	Olchawówka site 2, asterisk	Variegated shels	Subsequent	**dormant;** lack of geomorphic sign of movement	**active;** formation of a new niche with a steep scarp; transverse crack in the middle part, two major movement tracks; toe in form of accumulation heap with lobes
	Poddziele site 3, asterisk	Sub-Magura Beds	Insequent	**dormant;** lack of geomorphic sign of movement	**active;** movement of the entire form: formation of a new niche, transverse cracs in the head part, swamps in the middle part
	Kamionka Mała (nr 175) site 21, dot	Sub-Magura Beds	Consequent	**active:** movement of the entire form; complete removal of weathering cover, debris flows	**dormant** (stable?); lack of geomorphic signs of movement
	Laskowa site 15, dot	Sub-Magura Beds	not applicable	**active;** debris flow	**dormant;** lack of geomorphic signs of movement; rampart of 1997 completely removed by man
	Sechna site 6, asterisk	Variegated shales, Sub-Magura Beds	Subsequent	**active;** fragmentary movement in middle and lower parts	**active;** movement of the entire form: formation of a new niche, transverse cracks in the head and middle parts, dislocations in the accumulation zone

Gmina Pleśna	Szczepanowice sites 1 and 6, dots sites 5, 7, 15, asterisks	Sandstones and shales of Inoceramus Beds, marls overthrust zone	Complex	**active;** movement of the entire form; major dislocations in the lateral parts	**active;** renewal of the niche and formation of a high and steep scarp, transverse cracks, depressions with water table at the surface, dislocations in the lateral parts and at the toe
	Dąbrówka Szczepanowska site 7, dots	Sandstones and shales of Inoceramus Beds,	Complex	**dormant;** lack of geomorphic signs of movement	**active;** formation of a niche with a steep scarp, transverse cracks, accumulation of displaced material downslope
	Rychwałd sites 1 and 17, asterisks	Sandstones and shales of Inoceramus Beds, loess	Complex	**dormant;** lack of geomorphic sign of movement	**active;** renewal of numerous landslides on surrounding slopes, formation of niches with fresh scarps and development of step-like topography, bulges and mounds in the accumulation zone
	Łowczówek site 4, dots site 10–13, asterisks	Sandstones and shales of Inoceramus Beds, loess overthrust zone	Complex	**active;** movement of the entire form, formation of a new niche, transverse cracks, pushing by the toe	**active;** development of the niche, dislocations in the middle part, intensive movement at the toe
	Lichwin site 2, dots and asterisks	Shales of Istebna Beds loess overthrust zone	Complex	**active;** fragmentary movement	**active;** movement of the entire form

Sites numbering as in Figure 4.

tion threshold values. Based on the above L. Starkel (1996a) has presented the ideogram relating precipitation amount and its duration to extreme events of particular types. Typology of precipitation and associated processes being active in different slope and channel systems in the Polish Carpathians is elucidated in another paper by L. Starkel (1996b). Following such an approach the slope wash, soil flows, slips are associated with local, short-lasting downpours; the earthslides, earthflows, new landslides and re-activating of old forms are attributed to continuous rains; the deep earth- and rockslides and acceleration of permanently moving landslides are assigned to rainy seasons.

The threshold values of cumulative rainfall are also emphasised by E. Gil (1996) who analyses landslides in the region of Szymbark and demonstrates that the deep, debris-weathered material landslides on shale-sandstone and shale deposit occur under saturation conditions, when the storage capacity exceeds volume of water outflowing due to surface flow, throughflow and evapotranspiration. Such conditions are likely to be fulfilled during 20–45 days long period of rain amounting to 250–300 mm and of an average intensity. If the precipitation totals and duration are similar but the rainfall intensity increases, the surface flow, throughflow and evapotranspiration are responsible for water discharge from the slopes and shallow mass movements may be impelled. On the other hand, the landsliding on the slopes with sandstones prevailing in the bedrock is recorded when precipitation amounts to 400–500 mm during 20–40 days and the total exceeding 250 mm is reached in 5–6 days (Gil 1996).

Considering the number of incidences registered during the field work, the landsliding was more effective and hazardous in gmina Laskowa in 1997 but in Pleśna — in 2000. Within the framework of the above typology and threshold values, landsliding of July 1997 in both the gminas is related to an effect of the short-lasting downpours (storm precipitation) overlapped with the continuous rainfalis. However, gmina Laskowa was in the range of the higher precipitation than gmina Pleśna, as the rainfall was ceasing eastward (as pointed in the former sections). In gmina Laskowa the deposits were under saturation conditions due to the high antecedent precipitation (232 mm and 209 mm totals of May and June in Rozdziele and Limanowa, respectively). The critical rainfall of 4–9 July amounted to 242 mm in Rozdziele and 218 mm, so the landsliding was observed shortly after the storms of 9 July 1997. In other words, the mass movement took place when the values of the precipitation totals and critical rainfall reached almost the same order as the threshold values reported by E. Gil (1996). Other landsliding events in this region were related to the second phase of the storms of 18–20 July but the extent of mass movements was limited to the areas which did not reached stability until this time.

In gmina Pleśna, located farther east, the period preceding the landsliding was also wet but the totals of 39 days (from 1 June to 9 July) were lower and amounted to 217 mm in Wojnicz and 184.5 mm in Tarnów. Therefore, there is a lag between continuous rain and critical downpours, associated with the storm events of 18–20 July that were triggering factors for the major landsliding, here.

It should be emphasised that the year of 1997 belongs to so called wet ones — the annual precipitation totals significantly exceed the appropriate average values of precipitation in the period of 1951–1996 (by 26% in Limanowa, 36% in Rozdziele and 16% in Tarnów). Thus, the year of 1997 was an exemplary case of precipitation conditions necessary for development of landslides. In this respect the situation is similar to the intensification of summer landsliding earlier observed in relation to higher precipitation of years: 1913, 1934, 1974, 1980, 1985 in the Carpathians (Sawicki 1917; Ziętara 1968, 1974; Gil 1996; Starkel 1976, 1996b).

As indicated in the previous sections the landslides of 2000 were related to the series of snowmelts. The precipitation of 5 April 2000 (giving the highest precipitation this winter) comprised rainfall and snowfall in some locations. It was followed by additional snow falls related to the passage of the cold front and by an almost instantaneous thawing that was the triggering factor. At first blush, these events are very similar to those that caused the catastrophe in Duszatyn, described by R. Zuber and J. Blauth (1907) and W. Schramm (1925). However, the Duszatyn landslide occurred after the winter with extremely thick and long-lasting snow cover (Zuber and Blauth 1907) while the winter of 2000 was rather mild and the snowfalls were far from the extreme (except for November 1999). Moreover, in the winter season of 2000, several mid-winter thawing periods, allowing for saturation of the substratum were instrumental in setting the preliminary conditions for mass movements. The fact, that landslide incidences in gmina Pleśna substantially exceed those in Laskowa in this period can be attributed to lithology. The prevailing loess covers and Inoceramus beds with a content of bentonites in shales in the substratum in gmina Pleśna are more prone to landsliding. Similar findings are presented by A. Wójcik and Z. Zimnal (1996) when discussing landsliding in the San valley.

As far as the landslide typology of L. Bober (1984) is concerned the arrangement of rock layers or strata was of minor importance as clearly seen in Table 1. Independently of the type, almost all the analysed landslides were active both in 1997 and in 2000.

The performed examination showed that the weather conditions accelerate or trigger landslides, together with passive factors such as geological setting or land use. The dominant role of the meteorological factors is evident here, however, the development of mass movements cannot be attributed exclusively to the extreme events.

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STRESZCZENIE

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OSUWISKA AKTYWNE W OSTATNICH LATACH A UWARUNKOWANIA KLIMATYCZNE W GMINACH LASKOWA I PLEŚNA, POLSKIE KARPATY

W Karpatach fliszowych szczególnie duże nasilenie ruchów osuwiskowych obserwuje się w ostatnich latach. Na przykładach z gmin Laskowa i Pleśna zostały omówione uwarunkowania rozwoju osuwisk w terenach o różnej budowie geologicznej w 1997 i 2000. W obu omawianych obszarach stwierdzono, że decydującą rolę odgrywały czynniki klimatyczne, jako że ruch dotyczył różnych typów osuwisk (konsekwentnych, subsekwentych, złożonych). Wykazano, że w roku 2000 czynnikiem warunkującym rozwój osuwisk była sekwencja opadów śniegu i następujących po nich roztopów podczas względnie łagodnej zimy, w odróżnieniu od roku 1997, gdzie czynnikiem zasadniczym było nałożenie się opadów burzowych na deszcze rozlewne.