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LANDSLIDE HAZARD IN THE POLISH FLYSCH CARPATHIANS

Abstract. In the running year passes the 100th anniversary of printing the first Polish scientific description of landslide movements. The subject of this description was the landslide which occurred in the valley of the Olchowaty stream in 1907. This landslide took place up the village Duszatyn on the slope of Chryszczata Mt. (Zuber and Blauth 1907). The first and only as yet the registration of the landslides in Poland, in the 1960s, showed a significant landslide threat to buildings and technical infrastructure on the Carpathian slopes. Till now, 20,000 places of appearing of landslides have been counted. This is over 95% of all landslides in Poland. In the Polish Flysch Carpathians landslides belong to the most obvious, natural phenomena. The geological structure and morphology of the Carpathian slopes seem to be elements which result from local rather than regional conditions. Landslide activity is mainly related to the occurrence of extreme hydrometeorological conditions. Only this factor is relatively well recognized and described, among all the causes of landslides. The values of precipitation thresholds differ in particular mountain groups of the Polish Flysch Carpathians. It was established that duration and intensity of precipitation influence mechanism and type of landslides (Rączkowski and Mrozek 2002; Gil and Długosz 2006). A very intensive and chaotic building construction in the Carpathian valleys and on the slopes adds to larger and larger damages in the area every year. Infrastructure should be localized outside the areas where landslides occurred in the past and outside the areas with predisposition to landslides occurrence in the future. It is believed that the registration to be carried out in years 2008–2010, under “Landslide Protection Framework Project (SOPO)”, will contribute to limitation of construction activities on landslide areas.

Key words: landslides, triggering forces, hazard, Polish Flysch Carpathians

INTRODUCTION

Landslides, important landforms in the Carpathian area, not only did result in relief diversity but also bring about danger to infrastructure located on slopes. A very intensive and chaotic built-up in the Carpathian valleys and on the slopes adds to larger and larger damages in the area every year. Rejuvenation of old forms and formation of new landslides over so large area are the reasons of tremendous material losses. The latter amounts to hundreds of millions PLN. Ignoring landslide problems over many years, cause the hazards, com-

prising broader and broader areas, to grow in a mathematic progression. Predicting and forecasting these natural phenomena in mountain areas is extremely difficult.

This year is the 100th anniversary of publishing the first scientific description of damages, triggered off by sliding of earth masses on slopes of Chryszczata Range in the Olchowaty stream valley, up of Duszatyn village (Zuber and Blauth 1907). It was the first “catastrophe” related to landsliding, described and characterised as to its reasons. The paper presents also the first economic balance in terms of cost-benefits associated with mitigation and protection measures undertaken in the landslide-affected area.

The history of landslide studies has been outlined many times (Bober 1984; Rączkowski and Mrozek 2002; Rączkowski et al. 2004). However, the majority of papers in the field of interest deal with individual landslides or with selected geomorphological regions. A comprehensive overview of hazards related to mass movements in the entire Polish Carpathians is still lacking.

The first and only one, until now, registration of landslides was performed in 1968–1970 (Bażyński and Kuhn 1970). It resulted in identification of landslide areas along transportation routes and in urbanised terrains. In the Flysch Carpathians, over 8,500 landslides have been registered, out of which 2,970 caused danger to buildings and infrastructure. Again, out of this number 1,670 landslides were hazardous to houses, 49 to railways and 1,072 to roads, including national roads. The surface area of landslides inventoried in the 1960s amounted to 671.8 km², out of which 369.03 km² were referred to as active forms. As shown by A. Michałik (1970), 2.6% of the Carpathian area was occupied by landslides.

Summary of the studies on landslides until the end of 1980 was presented by L. Bober (1984). Since then, a significant progress has been made in inventorying landslides, i.a. when mapping sheets of the Detailed Geological Map of Poland 1 : 50,000. The recent, incomplete and fragmentary inventories of landslides in selected parts of the Carpathians were undertaken by the end of the 20th and the beginning of the 21st centuries (Poprawa et al. 1997; Rączkowski et al. 2004).

The “Map of the Polish Carpathian valleys under degradation due to mass movements and aggregate exploitation” as well as the “Map of landslides in the Polish Flysch Carpathians” in the scale of 1: 400,000 were cartographic overviews of the inventory results and of the studies of Carpathian Branch of the Polish Geological Institute. The first map was compiled by L. Bober (1994). The second map presents an impressive number of landslides — over 20,000 instances (Rączkowski 2000). The scale of “hazard due to mass movements” in the Polish Flysch Carpathians can be substantiated by a fact that the Carpathians occupy only 6% of the Polish territory, and over 95% of all registered landslide forms are found in the Carpathians. The Carpathian landslides are also very extensive. In many cases, the area of individual forms exceeds 1.0 km², and the largest landslide reaches the surface area of 13 km² (Bonarówka landslide — Bober et al. 1997).

TWO EXAMPLES OF CARPATHIAN LANDSLIDES

Zapadle landslide, on the slopes of Bartnia Góra Mt. in the Bielanka River valley near Szymbark (Fig. 1) is an active form (continuous movement of colluvial masses). When precipitation is higher the movement accelerates, when precipitation is normal the movement is a few times slower. The dynamics of the landslide movement was monitored in 1970s (Gil and Kotarba 1977, 1979) in the 1990s (Gil and Boczenek 1998) and in 2001–2006 (Rączkowski et al. 2006). This large (over 30 ha in surface area and over 1,000 m long), subsequent, structural, delapsive landslide moves at a rate of 1 mm/day (average from 5 posts located over the landslide tongue during 55 months of observations). The highest rate of movement (ca 2.0–2.5 mm/day) was observed in wet years in 2001–2003 while during dry years in 2004–2006 the rate of movement decreased to ca 0.17 mm/day. Displacements were accompanied by movements in the lower and middle parts of the tongue, delimited by lateral cracks running ca 400 m up-landslide. Zapadle landslide together with Huciska landslide, occurring at the opposite side

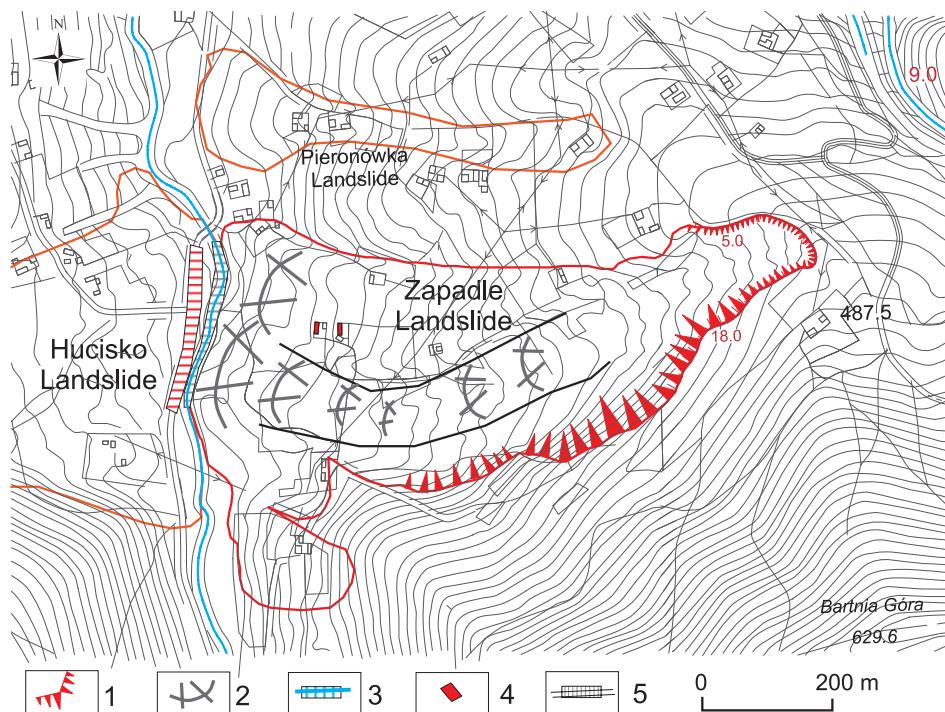


Fig. 1. The distribution of landslides in the Bielanka valley — the Zapadle and Huciska landslides. 1 — landslide niches, 2 — the most active, central part of the landslide, 3 — compressed section of the Bielanka stream, 4 — buildings threatened by destruction, 5 — yearly destroyed section of district (powiat) road

of the Bielanka valley, degrade annually ca 200 m long section of a district (powiat) road. Landslide stabilization is impossible due to economic reasons. In order to avoid damages and to prevent hazard it would be reasonable to shift the district road outside the landslide-affected area.

Lachowice landslide on slopes of Pierchalowa Góra Mt. (Fig. 2), rejuvenated in July 2001, is ca 400 m long and 700 m wide. The scarp of the old landslide body occurs at ca 545 m a.s.l. while the landslide tongue descends to the valley floor of the Lachówka stream to 441 m a.s.l. The rejuvenated part of the landslide (ca 11.7 ha surface area), in view of nature and distance of transportation, can be subdivided into SW, central, and NW parts. In the SW part, where a distance over which colluvium had been transferred is estimated for many tens of meters, the new landslide scarp reveals above the old scarp. In the NE part, only tiny dislocations took place, and upper and lateral cracks were observed in the 2/3 of the old landslide body height. Above them, at 530–520 m a.s.l. the old scarp, clearly marked in the terrain, is visible. In the rejuvenated part of the landslide, a 1.5–2.5-m-high amphitheatre-shaped scarp is visible.

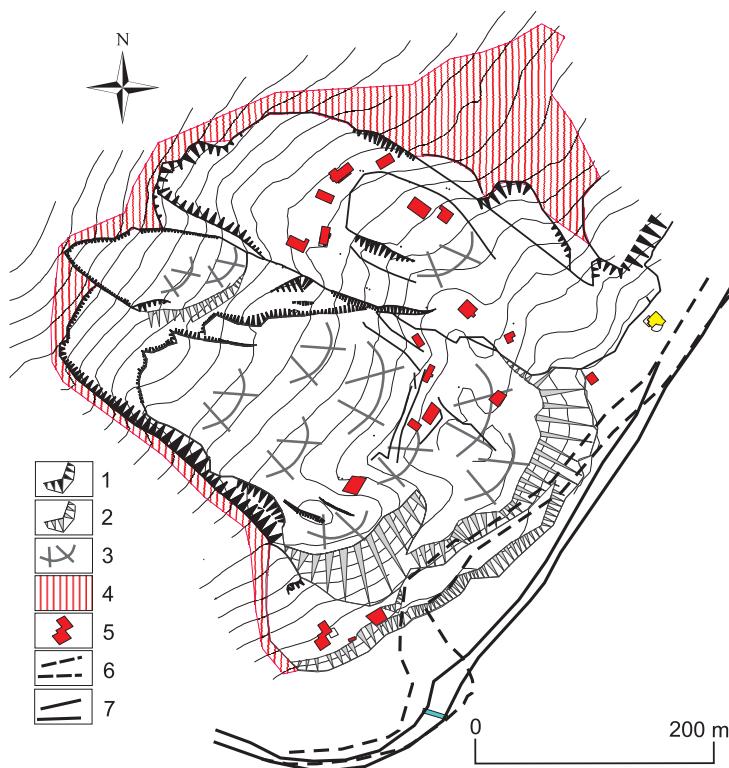


Fig. 2. The landslide at Lachowice. 1 — landslide niches, 2 — colluvial thresholds, 3 — colluvium of renewed part of the landslide, 4 — the ground threatened with mass-movements in the case of renewing of the landslide, 5 — buildings threatened by destruction, 6 — the course of the old river-bed of the Lachówka stream, 7 — the new trough of the stream (artificial digging)

theatre scarp, lateral cracks and a tongue, transferred up to 60–70 m and coming down to the Lachówka valley floor, can be distinguished. The tongue slid across the stream channel and generated a dammed lake over the valley floor. In the early spring of 2002 (sudden thawing by the end of January) the mass moments caused deformation of the scarp area — the scarp retreated ca 30 m uphill. The colluvium transferred due to the movements formed a 120-m-long and ca 5.0–6.0-m-high tongue. This is typical detrusive (not delapsive, as was suggested by M. Bajger-Kowalska (2002), consequent block-debris landslide. With respect to the type of movement, the central part of landslide can be classed as “flow” slide (Dikau et al. 1996), where colluvium oversaturated with water flowed along the downslope to the valley floor. In the SE part — in the slide, bedrock tectonics was important for landslide development. The tectonics was decisive i.a. for the landslide morphology and nature of movement. The tongue sides correspond well with local fault zones and fracturing (Rączkowski and Nescieruk 2005). In view of activity, the Lachowice landslide can be assigned to dormant landslides which are triggered only during extreme hydrometeorological conditions (summer 2001 and spring 2002). The ongoing monitoring indicates tiny vertical and horizontal movements of an order of a millimetre (Rączkowski et al. 2006). These movement are evidences of the colluvium compaction. The rejuvenation of Lachowice landslide resulted in damage of 12 houses while the following 38 are in endangered zone. The landslide has been reclaimed — 2/3 of surface area has been reforested. The total costs associated with transfer of infrastructure outside the landslide area and with mitigation measures exceeded 2.5 million PLN (over 600,000 €).

MAP OF CARPATHIAN LANDSLIDES

A map of Carpathian landslides is a compilation of digitized landslide data from various documentary materials, and particularly of digitizing data from the Detailed Geologic Map of Poland (DGMP) at the scale of 1 : 50,000. Due to a great diversity of the source materials, based on which the landslide map has been produced, various fragments of the map differ as to the degree of details. The only consistent source materials originate from DGMP sheets. Archival documentary materials, papers published in geologic periodicals and unpublished manuscripts have also been used. The landslide map is being updated, i.a. results of the studies performed in 2001–2006 allowed to increase the database of the Carpathian landslides by over 800 new landslide occurrences.

In the landslide map, there are regions where landslide clustering can be observed. On one hand, it is related to natural factors controlling landslide occurrences, on the second to accuracy and period when particular regions were mapped. The maps, being the outcomes of surveying in the 1950s and 1960s, present a definitely smaller number of inventoried landslides than the maps produced later on.

The indices of surface area of landslides (Op) and of landslide density (G), calculated for particular morphostructural units of the Carpathians by L. B o b e r (1984) and L. Z a b u s k i et al. (1999) are not longer valid. They do not illustrate landslide distribution in the Polish Flysch Carpathians. The number of recognised landslides and their total area have changed and, as a result, the values of the indices have changed as well. For example, in the case of Gorlice sheet of DGMP (K o p c i o w s k i et al. 1997) of the area of 334 km², the recognised landslides amounting to 370 occupy the total area of 33,897.7 ha, thus the landslide indices are: $G = 1.10$ and $Op = 10\%$. The above indices, as confirmed by later studies, illustrate quite well the distribution of landslides in the Beskid Niski Mts region. According to L. Z a b u s k i et al. (1999), the indices G and Op are 0.168 and 3.25, respectively. Mapping landslides at larger scales: 1 : 10,000 or 1 : 5,000 brings even a larger divergence between the results of earlier and present-day studies. The best example can be provided by the inventory of landslides performed in the framework of ALARM project in the catchments of Bystrzanka and Biczyska near Szymbark (M r o z e k et al. 2003, 2005). There 289 landslides have been registered over the area of ca 17 km², which leads to landslide indices $G = 17$ landslides/km² and $Op = 30\%$. Larger values of landslide area index Op used to be found only in small drainage basin in the Koszarawa catchment where the landslides occupy over 70% of the catchment area (Z i ę t a r a 1968; W ó j c i k 1997).

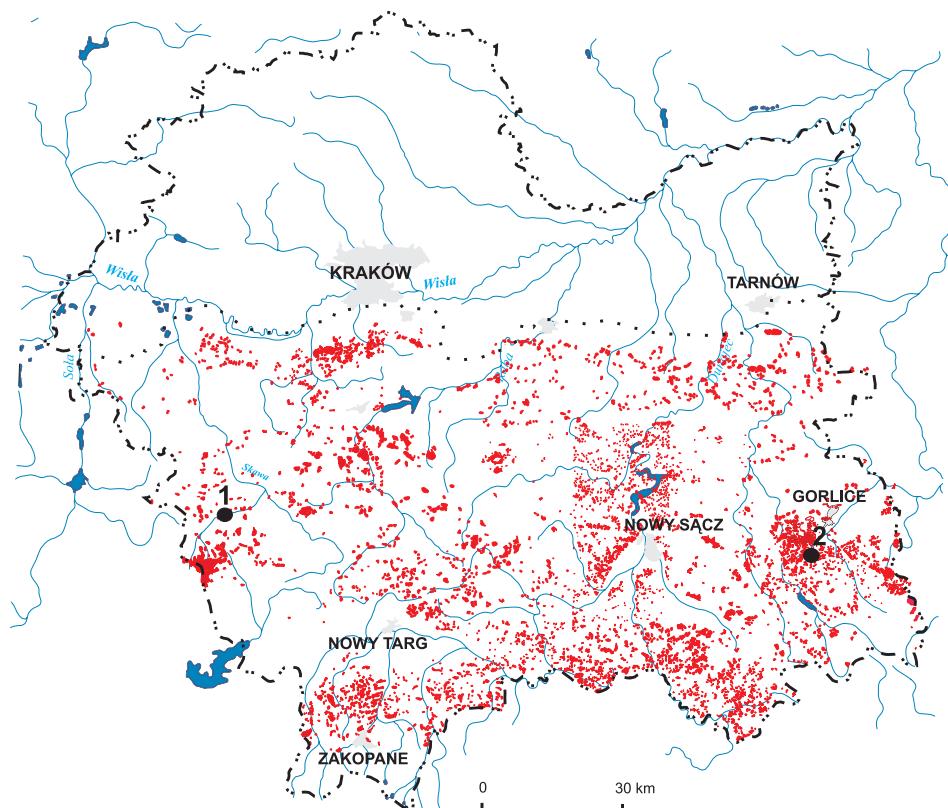


Fig. 3. The distribution of landslides in the central part of Polish Flysch Carpathians (the Carpathian part of the Małopolska province). The map drawn basing on materials of the Carpathian Branch, Polish Geological Institute
1 — Lachowice landslide, 2 — Zapadle landslide

Landslide distribution in the Polish Flysch Carpathians is depicted in the “Map of landslides in the Polish Flysch Carpathians”, whose fragment are given in Figure 3.

Among the “landslide-forming” factors, acting on a regional scale, L. Bober (1984, 1994) assigned the first rank to river erosion (sustained by neotectonic movements), the second to atmospheric precipitation, and then to seismicity and human activities. L. Bober’s (1984, 1994) geological view on the Carpathian landslides has been completely transformed due to results of the research of the Institute of Geography and Spatial Organization Research Station in Szymbark (Kotarba 1970, 1986; Froehlich and Starkel 1987; Gil 1994, 1996; Gil and Bochenek 1998; Gil and Starkel 1979; Starkel 1996), and later due to a significant moistening of climate by the end of the 20th and the beginning of the 21st centuries. Extremely high precipitation, which occurred over that time, caused changes in the approach to the occurrence and triggering conditions of mass movements. Enormously high precipitation of July 1997 and the later, even higher, precipitation of July 2001 triggered landsliding on a scale which have not been observed in the Carpathians yet. Summer precipitation combined with spring snow melting have contributed and are contributing to annual rejuvenation of landslides associated with infiltration of meltwater into landslide colluvium covers (e.g. spring of 2000 and 2002). Considering all the above, the atmospheric precipitation triggering factor is now given the first rank. L. Starkel (2002, 2006) describes a specific “cluster of extreme events” which started with catastrophic atmospheric precipitation in summer of 1996 and which manifests itself in the Carpathians by activating landslide processes after precipitation of July 1997. Without time needed for relaxation, the events forming this cluster lasted over several years in a raw until 2002. A precise determination of an end of the events forming the cluster is very difficult. After a long, 15 years lasting, period of landslide “quietness”, slope instability set off in 1997–2002 seems to continue. As it can be observed in 2002–2006, monthly precipitation slightly exceeding the multi-annual average (of the order of 200 mm/year) is sufficient to trigger mass movements.

In the case of landslides classed as active, the movement of colluvium in the period of spring melting and summer moistening, associated with “summer precipitation” in the Carpathians, manifests itself in its increased rate (Zabucki et al. 2004; Rączkowski et al. 2004; Bednarczyk 2005). These movements, that only can be observed using deep (inclinometer) and precise geodetic surface monitoring, result in damages in “landslide fragments” of roads and of building located on slopes.

River erosion became less important as often there are no direct links between slope systems and river channel systems, due to channelization of rivers and streams which used to undercut the slopes. Moreover, water level fluctuations are smaller due to operating dams and storage reservoirs built. A good example is the dam in Klimkówka, which reduced intensity of river erosion and intensity of mass movements, compared to the years prior to its construction at the Ropa river (Krąpiec and Rączkowski 2005).

Seismic quakes seem to be of historical importance in the Polish Flysch Carpathians. Landslide in Lipowica (located in a gorge of the Jasieńka valley in the zone where the Dukla Unit is thrust over the foreland (Badałek and Pawłowski 1959; Gerlach et al. 1958), rejuvenated in 1957 due to seismic activity, was the last one associated with earthquakes in the Carpathians. However, in many papers there are comments on landslides associated with the earthquakes which took place among others in the Moravian–Silesian Beskid Mts, Beskid Żywiecki Mts, Gorce, Beskid Sądecki Mts, Beskid Niski Mts, and Pieniny mountains in the historical times (Adamczyk 1979; Wójcik 1997). The problems of the Carpathian earthquakes have been described in several papers which elucidate, among others, macroseismic zones (Pagaczewski 1972; Hojny-Kołos 1997; Gutertch and Lewandowska-Marciniak 2002). Seismic issues cannot be disregarded when considering hazards related to mass movements. There is a permanent threat associated with probable occurrence of earthquakes (Poprawa and Rączkowski 2003). The most hazardous zones are illustrated in Figure 4. According to B. D. Malamud's et al. (2004) studies, a shock necessary to trigger mass movements has to exceed $M > 4.3 \pm 0.4$. The shocks of such magnitudes were recorded in the Carpathians: in the Moravian–Silesian Beskid Mts in the 15th and 19th centuries, and in the Pieniny region in the 19th and 20th centuries (Pagaczewski 1972).

Human activity seems to have a little influence on the development of mass movements in the Carpathians. Landslides have a rather pejorative impact because they bring about damages and destruction of the infrastructure built on the landslides. A particular case is situating roads and houses in the regions where the landslides have not been recognised earlier. The costs of damaged road reconstructions often exceed investment costs. An example is a bypass of Mogilany along the road Kraków–Zakopane. Out of the planned 35 million PLN (in prices of the 1970s), the cost of the 3.5 km long bypass increased the investment costs to 89 million PLN owing to the need of recognition and stabilising five landslides (Królikiewicz 1978, 2000). The “stabilised” landslide still damage the road from year to year. According to the performed examination, the discussed road in the section from the Carpathian border to the Podhale basin was threatened by 54 landslides. During the ongoing construction of the second lane of the road in the mountainous region, new landslides can reveal or form in association, among others, with slope undermining or with putting the road across old, unrecognised landslides. The majority of landslides, during the constructing the second lane of the discussed road in the section between Myślenice–Lubień, required highly specialized geotechnical measures, i.e. large diameter drilled piles.

Identification of landslides in the areas of planned hydrotechnical investments is particularly important. Water reservoirs affect slope instability due to seepage pressure and water rise in colluvium (Bobr 1984). After the WW2, due to numerous landslides occurring on the sides of river valleys where water dams were planned to be build, such intents were abandoned at Stróża in the Raba val-

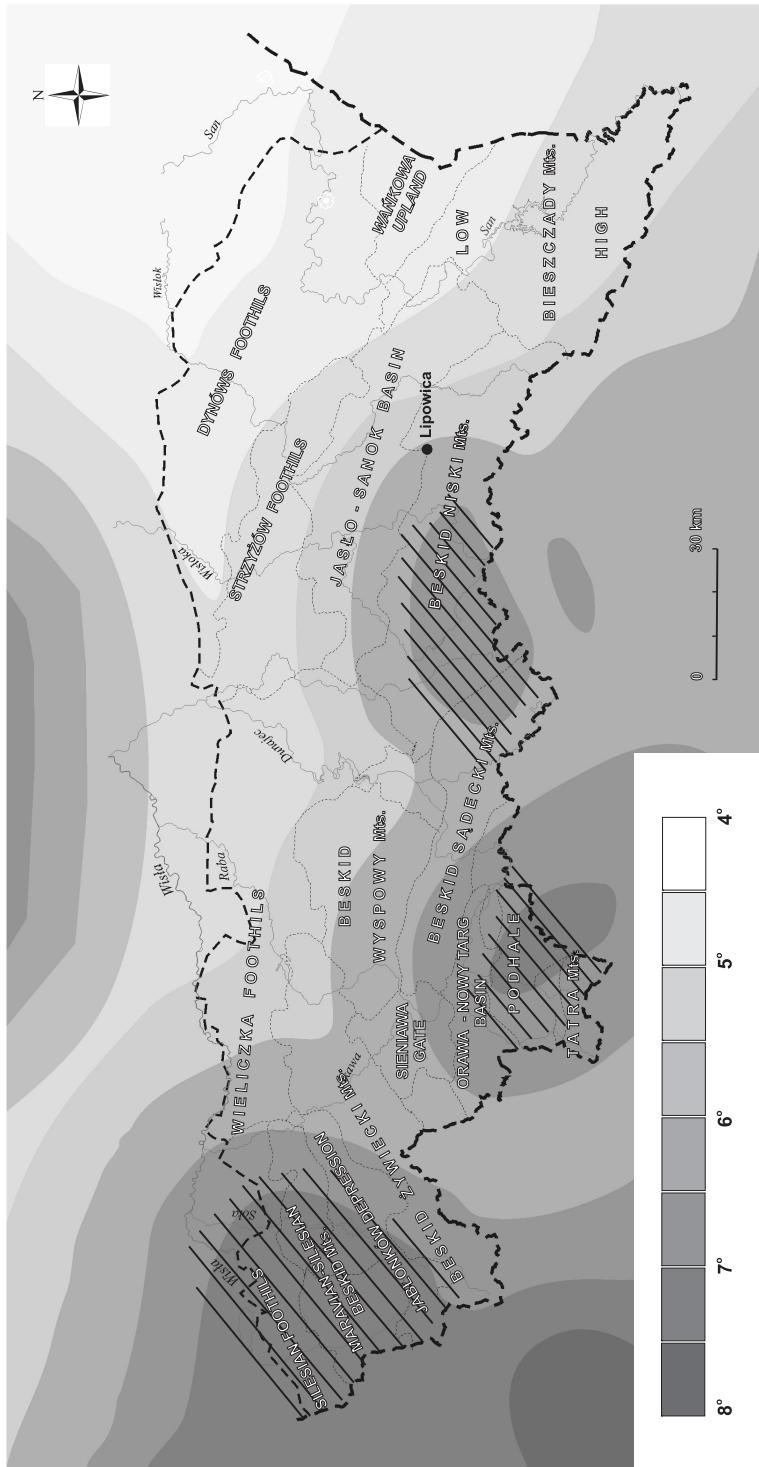


Fig. 4. Earthquake hazard in the Polish Flysch Carpathians. Macroseismic zones — the intensity in the MSK scale (after V. Schenk et al. 2001; vide: B. Gutertch, H. Lewandowska-Marciniak, 2002). With slant hachure are marked areas with landslides threatened by earthquakes

ley, at Kojsówka in the Czarny Dunajec valley, at Krasiczyn on the San river. Constructing the water reservoir in Kąty near Krempna, where A. Wójcik inventoried several landslides in the region of the planned dam and the backwater area (Wójcik and Rączkowski 2002), becomes problematic. The same might happen in the case of other planned water reservoirs, as the landslides occurring on the Carpathian slopes will cause slope instability above the line of banking up. The Roźnów reservoir can serve here as an example. The old landslides occurring on the slopes became active after filling up the reservoir with water and they cause danger and damages to houses and road network. A single landslide at Zbyszyce is hazardous to 89 houses and to district and municipality roads (Wojciechowski 2007). According to inventory of 1997 and of the later ones, the areas of municipalities surrounding the Roźnów reservoir belong to the most landslide prone areas (Poprawa et al. 1997).

As results from the papers by L. Bober (1984), L. Bober and N. Oszczypko 1975, L. Bober and A. Wójcik (1977), J. Kukulak (1988), A. Wójcik and Z. Zimnal (1996), A. Wójcik (1997), W. Margielewski, (2002, 2006a), A. Wójcik et al. (2006) and many others, it is impossible now to show definitely regularities in landslide distribution and conditioning associated with passive factors, i.e. resulting from geologic setting — lithology, tectonics and relief. During the detail works related to geological-engineering documentary of particular landslides performed in recent years, it turns out that landslide development depends on local geologic conditions of the slopes where the landslide occur rather than on regional conditions associated with particular lithostratigraphic flysch members. The frequently described relations between landslides and fold and disjunctive tectonics are not fully clear, and deciding which of them is a dominating is practically still impossible.

The stated at least in recent years, rejuvenation of old, existing for hundreds or even thousands of years, large structural landslides (Margielewski 1998, 2006b) and to a lesser extent, formation of new landslides allows one to conclude that the fragments of slopes which have been destabilised once are more prone to mass movements than those fragments of slopes whose structure has not been altered yet. Lower intensities of the triggering forces are sufficient to set off movement of colluvial masses of old landslides.

According to the majority of the studies carried out in the discussed region, among the active factors, the atmospheric precipitation, water related to snow melting in spring and fluctuations in groundwater table are of a great importance (Thiel, ed. 1989; Zabuski et al. 1992; Gil 1996, 1997; Gil and Starkel 1979; Gil and Kotarba 1979; Gil and Bochenek 1998; Rączkowski and Mrozek 2002; Zabuski et al. 2004; Gil and Długosz 2006). The sum of precipitation initiating the mass movements is called “precipitation threshold” (Froehlich and Starkel 1987). The values of threshold precipitation vary for regions of different geology (Govi et al. 1982; Rączkowski and Mrozek 2002; Gil and Długosz 2006; The RISK-AWARE Project). It is emphasised here that

the threshold values of precipitation initiating mass movements are diversified in various physical-geographic regions of the Carpathians.

Summarising the papers published until now it has been stated that:

- mass movements under conditions of medium moisture of the ground can occur after precipitation exceeding 200 mm and of duration of a few to a dozen days;
- precipitation exceeding 250–300 m and of the same duration will trigger structural, rock-debris landslides on the slopes built of shale and normal flysch;
- precipitation exceeding 500 mm (monthly sums and sums of long-period precipitation) during several tens of days can trigger deep structural landslides on the slopes built of sandstone flysch; such precipitation occurred in the Carpathians in 1980, 1997, 2001 and were of extreme values. Exceeding of this threshold causes the “landslide catastrophe” in the Carpathians (*sensu* Rączkowski and Mrozek 2002).

Usually, when the average monthly precipitation is exceeded twice or three times it triggers landsliding in the given area, and the mechanism and type of landslide movement depend on intensity and duration of precipitation (Rączkowski and Mrozek 2002; Gil and Długoś 2006).

SUMMARY AND CONCLUSION

There is a great complexity of conditions related to occurrence and development of landslides, as was shown above when discussing two example landslides. Triggering and development of landslides depend on passive and active factors, which directly result from elements of natural environment, especially from: geomorphological, geological, and hydrometeorological conditions. However, precise determination of relation between above mentioned conditions is very difficult based on a present-day recognition of geographical environment of the Polish Flysch Carpathians.

In the area of such great diversity of relief and geology (both lithology and tectonics), landslides belongs to the most obvious, natural phenomena. Their activity is mainly related to occurrence of extreme (extraordinary) hydrometeorological conditions. Only this factor is relatively well recognized and described, among all the causes of landslides. The values of precipitation thresholds differ in particular mountain groups of the Polish Flysch Carpathians (Rączkowski and Mrozek 2002; Gil and Długoś 2006). It was established that duration and intensity of precipitation influence mechanism and type of landslides. The great randomization, both in space and time, is a characteristic feature of rapid and short-term downpours, as well as of heavy rainstorms in the whole the Polish Flysch Carpathians, which makes the main difficulty in prognosis of landsliding.

The registration of landslides at the end of the 1960s, only as yet, embracing the entire area of Polish Flysch Carpathians, revealed a great risk related to landslide occurrences in the region. Due to many causes, this registration was not all inclusive and therefore did not result in a definitive image of hazards related to mass movements in the Polish Flysch Carpathians.

Many landslides, destructive and threatening to infrastructure, are not stabilized because of difficulties involved and lack of reasonable economic premises. Housing and transportation infrastructure should be localized outside the areas where landslides occurred in the past, and outside the areas with predisposition to landslide occurrences in the future. This will be possible to achieve by changes in the Polish legislation and detailed registration of landslides in the framework of the Component B of the Project "SOPO". This Project will be accomplished using European Investment Bank loan. Mapping in scale 1 : 10,000 should result in registration of more than 50,000 landslides in the Polish Carpathians.

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STRESZCZENIE

Wojciech Rączkowski

ZAGROŻENIE OSUWISKAMI W POLSKICH KARPATACH

W roku bieżącym mija 100. rocznica wydrukowania pierwszego polskiego artykułu opisującego zjawiska osuwiskowe w polskich Karpatach. Osuwisko opisane przez R. Zubaera i Z. Blautha w 1907 r. miało miejsce w dolinie potoku Olchowatego na stokach góry Chryszczatej powyżej Duszaźna. Jedyna jak dotąd rejestracja osuwisk w Polsce, przeprowadzona w latach 1960, pokazała duże zagrożenia związane z osuwiskami na terenie polskich Karpat. Dotychczas rozpoznano 20 000 miejsc ich występowania, co stanowi ponad 95% wszystkich osuwisk w Polsce. Zjawiska te należą do najbardziej naturalnych zjawisk przyrodniczych w górnym regionie Karpat. Powstanie i rozwój osuwisk zależy bardziej od lokalnych warunków budowy geologicznej i rzeźby stoku, na którym występuje osuwisko, niż od warunków regionalnych. Aktywność osuwisk związana jest głównie z występowaniem warunków hydroeteorologicznych. Jedynie ta przyczyna jest w miarę dobrze rozpoznana spośród innych wynikających z warunków przyrodniczych Karpat. Wartości progowe opadów inicjujących ruchy masowe są różne w poszczególnych regionach górskich Karpat fliszowych (Rączkowski, Mrozek 2002; Gil, Długosz 2006). Od natężenia i czasu trwania opadów zależy mechanizm i typ ruchu osuwiskowego. Bardzo intensywna i chaotyczna zabudowa karpaccich dolin i stoków przyczynia się do coraz większych strat ponoszonych corocznie na tym obszarze. Musi ona być lokalizowana poza obszarami występowania osuwisk i obszarami predysponowanymi do ich wystąpienia w przyszłości. Prawdopodobnie rejestracja osuwisk przeprowadzona w latach 2008–2010, w ramach projektu “System Oslony Przeciwasuwiskowej (SOPO)” przyczyni się do rozwiązania tego problemu.