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TYPES OF LANDSLIDES AND THEIR GEOMORPHOLOGICAL ROLE IN THE CARPATHIAN FOOTHILLS MARGINAL ZONE BETWEEN THE RABA AND USZWICA RIVERS

Abstract: The paper presents a detailed study of the distribution and present-day transformation of landslides in the Carpathian Foothills marginal zone between the Raba and Uszwica rivers. The result of this study is a typology of landslides and landslide-creep forms based on their morphology, size and present-day activity. The spatial distribution of identified types of forms allowed the morphological role of gravity-driven processes in the modelling of the Carpathian Foothills to be determined.

1. Introduction

The process of land sliding is based on the gravity-driven displacement of rock and rock-weathering mantle on a slope. This process is common in the flysch parts of the Carpathians (Starkel, 1960). Research on landslides in Poland was initiated at the turn of the 19th and 20th century (Gerlach, 1976). In many areas of the Carpathians landslide processes are being attributed a particular role in the present-day transformation of relief (Wójcik, 1958; Ziętara, 1968a). The literature on land-sliding in the Carpathians is quite extensive. Many of the publications present monographic studies of slides, their development trends and the mechanisms of sliding processes themselves (Jakubowski, 1965, 1967, 1974; Kleczkowski, 1955; Kordaszewska, 1968). There are only a few publications presenting the diversity and morphological role of landslides within the Carpathian Foothills marginal area. Only Kotarba (1986), Starkel (1957) and Ziętara (1974) address this issue from a broader perspective. They are finding that because of geological and geomorphological contrasts, the marginal zone of the Foothills is intensively modelled by gravity-driven processes. These processes are decisive for the further geomorphological development of the area. On the other hand, they cause significant economic damage. Slopes modelled by sliding and creeping processes are not suitable for building construction and most frequently are idle land.

The high intensity and activity of these processes cause the destruction and burial of roads and railways. Thus an investigation of the morphological role of land sliding processes, the spatial distribution of their forms and their present-day activity became the aims of this study, carried out in 1995.

The research project was based on the inventory of forms occurring in the area and the determination of their morphometric and morphological characteristics. This allowed the extent of the present-day transformations of landslide forms to be determined, along with the impact of local environmental conditions on their distribution within the Carpathian Foothills. The analysis of form development and their present-day activity allowed the creation of a landslide typology. Because of the agricultural activities in the region, predicting the intensity of gravity-driven processes is particularly significant. It will allow protection measures to be undertaken to minimize the economic damage caused by the occurrence of these phenomena.

2. Study area

The area covered by the study (33 km^2) is located within the lower step of the marginal zone of the Wieliczka Foothills (a sub-region of the Carpathian Foothills). It is adjacent to the Sandomierz Basin, which influences the air flow direction at the foot of the Carpathians. The major rivers dissecting the northern escarpment of the Foothills are oriented north-south (Fig. 1). The boundaries of this area are the escarpment in the north, the Raba river valley in the west and the Uszwica river valley in the east. The southern borderline of the area is located along stretches of the Stara Rzeka, Spytkowski stream and Łapczycki stream valleys, which are parallel to each other. Urban areas including the towns of Bochnia and Brzesko were not taken into account.

The older Cretaceous-tertiary bedrock consists of Silesian and sub-Silesian flysch units. These are built of interbedded layers of sandstones and slates of variable thickness (Unrug et al., 1996). Lithological and structural features typical for flysch are favourable for landslide development in the Carpathians as a whole. In the area under investigation the flysch bedrock is covered by Quaternary formations of which the most common are loess-like deposits of a dozen metres or so in thickness (Święchowicz, 1991).

These formations formed *Haplic Luvisols* and *Stagnic Luvisols* (Skiba, Klimek, 1992). The characteristic elements of the Wieliczka Foothills are the wide, elongated and parallel ridges related to the main geological structures of the region (Tutaj, 1995). Flattened hummocks are dissected up to a depth of 100 metres. Slopes are long and convex-concave profiled, with gradients rarely exceeding 25^0. Most of them smoothly transform into wide valley plains. Young valleys are common in the eastern parts of the area, dominated by V-shaped incisions and gullies. The northern and western parts of the area are dissected by basin-shaped valleys, often with wet plains (used for agricultural purposes). The thick weathering covers and a dense network of small valleys create adequate conditions for gravity-driven movement of earth-masses. Continuous sectioning of slopes and the removal of the material have lead to the uneven slope retreat and formation of landslide headwalls and lobes.

The studies by Pietrzak (1998) demonstrated that the multi-step process of human settlement in this area was initiated in the 10th century and by 1500 the area was completely populated. The settlement pattern created at that time has survived to the present day. The intense exploitation of the natural environment has caused the fragmentation of farms, an increase in road density and a significant decrease in forest-covered areas (by 90% locally as compared to the forest area in the 17th and 18th centuries). At present this area is characterized by a maturity of relief, which may influence the low intensity of geomorphological processes (Michno, 1995; Tutaj, 1995).

3. Landform characteristics and distribution

Ninetytwo landslide and landslide-creep forms with a total area of 238.7 hectares were identified within the study area. Their origins are quite complex. Only 40 forms are typical landslides, with a clearly discernible niche and accumulation zone. Landslides occupy 3.1% (102.3 hectares) of the investigated area. The remaining 52 forms, modified by present-day processes of sliding and creeping were referred to as landslide-creep forms (Fig. 1). These forms account for 136.4 hectares, which is 4.1% of the investigated area (Michno, 1995).

Within the area of investigation, landslides and landslide-creep forms occur on valley sides (48 forms, 108.4 hectares), in the initial parts of valleys (25 forms, 72.2 hectares) and on hill slopes (19 forms, 58.1 hectares) (Fig. 2). The valley slope forms are the smallest in size but they occupy a total of 46% of

Fig. 1. Distribution of forms.

Ryc. 1. Rozmieszczenie form.

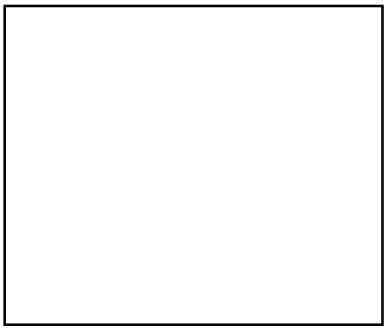

Fig. 2. Morphological position of landslides and creep-forms.

Ryc. 2. Położenie morfologiczne osuwisk i form osuwiskowo-złaziskowych.

the area modelled by sliding and creeping processes. Hill-slope forms are the largest in size. Individual forms often exceed five hectares. Because of their small number, these forms account for only 24% of the gravity-modelled area (Tab. 1).

Slides occur within the elevation belt of 198-345 m a.s.l. and in 80% of the cases they are exposed to the humid air masses advecting from the N, W, NW and SW. Of the landslide-creep forms 73% have similar aspects. The morphometric diversity of forms with different exposures is low. Forms exposed to the advection of humid air-masses have similar morphometry to other forms. Aspect has a significant influence on the number of forms and their present-day transformations (Fig. 3, Tab. 2). The consequent valleys dissecting the marginal zone of the Carpathian Foothills have asymmetrical sides that are probably tectonically conditioned. The valley sides exposed to the west are higher and steeper than the opposite ones. They are intensively modelled by gravity-driven processes. Exposure to the advecting rain-bearing air-masses has supported recent activity of the slope processes.

The slides (40 cases) have a clearly discernible niches of semicircular shape, whose edge height ranges between 1.6 and 14.4 m. The relative heights within the colluvia accumulation zone can reach as much as 7 m. The microrelief is best preserved on

Fig. 3. Exposure of landslides and lanslide-creep forms; A - number of forms, B - surface area of forms.

Ryc. 3. Ekspozycja osuwisk i form osuwiskowo-złaziskowych; A - liczba form, B - powierzchnia form.

Tab. 1. Diversity of forms' morphometry versus their morphological position.

Tab. 1. Zróżnicowanie morfometrii form o różnym położeniu morfologicznym.

Value / Wartość	Altitude of the upper limit of the form m a.s.l. / Wysokość górna formy m n.p.m.	Altitude of the lower limit of the form m a.s.l. / Wysokość dolna formy m n.p.m.	Form height m / Wysokość względna m	Mean inclination ° / Nachylenie średnie °	Maximum length m / Długość największa m	Maximum width m / Szerokość największa m	Area ha / Obszar ha
Slope forms - Formy stokowe							
Maximum Największa	293	261	57	30	350	405	9.7
Minimum Najmniejsza	248	202	14	9	46	74	0.1
Średnia Mean	270	236	34.7	18	196	186	3.1
Forms in initial parts of valleys - Formy początkowych odcinków dolin							
Maximum Największa	350	330	44	39	335	360	6.3
Minimum Najmniejsza	264	240	10	13	87	90	0.1
Mean Średnia	317	290	26	22	182	176	2.9
Valley-side forms - Formy zboczowe							
Maximum Największa	348	297	56	32.4	360	425	10
Minimum Najmniejsza	230	198	2	8.1	15	6	0.1
Mean Średnia	270	243	27	20	160.6	149	2.3

wide slides, probably the oldest, which have had multi-stage development histories. The landslide-creep forms (52 sites) most frequently do not have discernible niches. Their area is large and undulations within the material accumulated reach up to 3.8 m. The morphometry of these forms is probably linked with the genetic type of processes modelling their surface (Tab. 3).

4. Extent of form transformation and activity

Information on the distribution, size and extent of the present-day transformation of slides and landslide-creep forms allows their role in the development of the local relief to be determined. The detailed description of all 92 forms makes it possible to draw conclusions concerning their relative age and present-day activity.

Tab. 2. Morphometric diversity of forms versus their aspect.

Tab. 2. Zróżnicowanie morfometryczne form o różnej ekspozycji.

Value Wartość	Altitude of the upper limit of the form m a.s.l. Wysokość górna formy m n.p.m.	Altitude of the lower limit of the form m a.s.l. Wysokość dolna formy m n.p.m	Form height m Wysokość względna m	Mean slope ° Nachylenie średnie °	Maximum length m Długość największa m	Maximum width m Szerokość największa m	Area ha Obszar ha
Aspect -Ekspozycja: N, NW, W, SW							
Minimum Najmniejsza	30	198	5	8.1	20	36	0.1
Maximum Największa	350	330	57	39	360	405	9.7
Mean Średnia	271.3	244.4	26.8	9.4	151.5	157	2.7
Aspect - Ekspozycja: NE, S, E, SE							
Minimum Najmniejsza	231	247	2	13	15	6	0.3
Maximum Największa	349	320	53	35	360	425	10
Średnia Mean	310	282.8	27.6	22.5	205.3	175	2.3

In the flysch zone of the Carpathians, appropriate conditions for the development of landslides occurred at the end of the last glaciation, during the Atlantic and sub-Atlantic periods (Starkel, 1960, 1972). The morphometric features of all the forms identified and the extent of their transformation indicate that most of them were formed during the Holocene and only a few of them are older. Undoubtedly some of the present forms arose from older ones which went through a complete or partial renewal. The staged development of landslides in the Carpathians was also confirmed by Starkel (1957, 1960), Świderski (1932), Teisseyre (1936) and Ziętara (1964). It should be remembered that the extent of form transformation is not always a good indicator of its age. The present-day period of stabilization, reflected, among other things in the smoothening of the niche edges and the disappearance of the traces of slide accumulation, can be one of the development stages of the form in the so-called slide cycle (Jakubowski, 1974). In the flysch Carpathians, the main factors determining the course of sliding processes are the geological structure and precipitation variability on annual and long-term scales. Monitoring studies of the slide processes carried out near Szymbark confirm an increase in the activity in these processes in summer (maximum precipitation) and in spring (thaw). In long-term profiles, the intensity of gravity-driven processes increases during the so-called wet-years (11-year meteorological cycle) (Śliwa, 1995).

Tab. 3. Diversity of the morphometry of landslides and landslide-creep forms.

Tab. 3. Zróżnicowanie morfometrii osuwisk i form osuwiskowo-złaziskowych.

Value Wartość	Altitude of the upper limit of the form m a.s.l. Wysokość górna formy m n.p.m	Altitude of the lower limit of the form m a.s.l. Wysokość dolna formy m n.p.m	Form height m Wysokość względna m	Mean slope ° Nachylenie średnie °	Maximum length m Długość największa m	Maximum width m Szerokość największa m	Area ha Obszar ha
Landslides - Osuwiska							
Minimum Najmniejsza	230	198	2	10.8	15	6	0.1
Maximum Największa	342	316	57	35	340	405	10
Mean Średnia	271.4	241.2	29.5	22.8	160.7	152	2.6
Landslide-creep forms - Formy osuwiskowo-złaziskowe							
Minimum Najmniejsza	235	202	10	8,1	25	36	0.1
Maximum Największa	350	330	56	39	360	425	6.3
Mean Średnia	291.6	264.5	27.3	19.5	198.8	190	2.6

According to the classification by Jakubowski (1974) the analyzed forms are either at the stage of secondary slide displacement or are stabilized. Secondary sliding movements, along with denudation and erosion processes are the cause of present-day form transformation along with denudation and erosion processes. The presence of zones with higher dynamics, the lack of fresh erosional incisions and the discernibility of particular elements of slide morphology (eg the steep walls of the niches) are indicators of a form's contemporary activity. Significant transformations of the slide area by denudation and erosion processes indicate a stage of maturity and stability of a form (Fig. 1).

The periodically active forms occupy 164.1 hectares (68.7% of the area of all 92 forms), including active slides (73.7 hectares). Among all the forms whose microrelief indicates periodical activity, 75% are north or west exposed. The status and activity of the forms are thus dependent on climate conditions. Stable forms, with a mature relief of the slide, occupy 74.6 hectares (31.3% of the total area of the 92 forms), of which 28.6 hectares are solely modeled by slide processes. The relationship between the development stage and activity of a slide and the annual precipitation pattern is not always of prime importance (often other local environmental conditions such as lithology and relative heights are more significant).

5. Landuse in landslide areas

At present, the impact of climate conditions on the development and activity of landslide forms is less important than the impact of human activities (Jakubowski, 1974). In many areas of the Carpathians, deforestation initiated the development and transformation of landslides. Table 4 and Figure 4 show the current extent of landuse (vegetation cover). It should be emphasized that more than 35% of the area of periodically active forms are farmlands, while only about 10% of the forms' area is forested. The frequent activity of landslides and landslide-creep forms discourages from bringing of the land under cultivation.

Contemporary changes in land use patterns and building on slopes most frequently induce shallow creep processes. The activity of deeper sliding movements rather depends on local geological and geomorphological contrasts. Forms generated by mass processes can also become local traps for transported matter, including pollutants (Kaszowski, 1995).

Tab. 4. Management patterns of landslides and landslide-creep forms.

Tab. 4. Użytkowanie osuwisk i form osuwiskowo-złaziskowych.

Landuse Użytkowanie	Total area of all forms Obszar form ogółem	Area of active forms Powierzchnia form aktywnych			
		All active forms Wszystkie formy		Active landslides Aktywne osuwiska	
	ha	ha	%	ha	%
Green crops Użytki zielone	33	22	13.4	21.8	29.6
Green crops, arable land Użytki zielone, pola orne	20.7	2.7	1.7	-	-
Green crops, orchards, arable land Użytki zielone, sady, pola orne	24.9	17.6	10.8	7	9.6
Green crops, orchards, arable land Użytki zielone, sady, pola orne,	14.0	14.0	8.5	3.8	5.3
Green crops, arable land, forests Użytki zielone, pola orne, lasy	26.9	23.8	14.5	13.8	18.7
Green crops, forests Użytki zielone, lasy	65.5	39.2	23.8	11.2	15.0
Green crops, orchards Użytki zielone, sady	18.3	17.5	10.6	7	9.6
Green crops, forests, orchard Użytki zielone, lasy, sady	11.2	11.1	6.8	4.5	6.2
Lasy Forests	23.4	16.2	9.9	4.5	6

6. Typology of landslide forms and landslide areas

A typology of landslides and landslide-creep forms was established to investigate their diversity (Michno, 1995). The main criteria assumed for this typology are the area of a form and its present-day activity. The area of a form provides indirect information on the process intensity. The present-day activity and extent of transformation of a form allow conclusions to be drawn on its relative age and stage of development. The specification and analysis of the above features led to the identification of four types of slides (designated A, B, C and D) and four corresponding types of landslide-creep forms (A1, B1, C1 and D1).

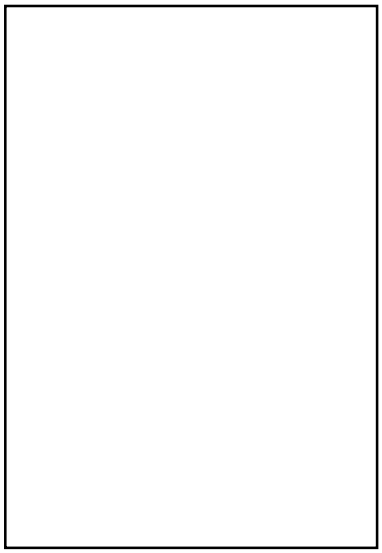

Fig. 4. Present-day use of forms.

Ryc. 4. Współczesne użytkowanie form.

6.1. Types of landslides

Type A - large, periodically active landslides. There are 12 valley-slope slides, five hill-slope slides and three slides in the initial sections of valleys. These forms occur mainly near the village of Chełm and town of Brzesko. Most of the slides within this type are exposed north or west. They are large forms, at the stage of secondary sliding displacement. These slides occupy an area of about 69.2 hectares (68% of the total area of slides). The size of the forms reflects the intensity of the process.

Type B - large and stable landslides. These forms include eight slides occupying a total area of 25.6 hectares (25% of the total area of slides). They occur mainly in the central part of the area investigated, and their genesis is linked with local hydrological conditions. There are four valley- side forms, three in the initial sections of valleys and one hill-slope form. Despite their north or west aspect (75%) they are not currently active. Slides of this type are probably older than Type A forms, although we may suppose that the intensity of the processes was quite significant, because the individual forms have large areas.

Type C - small, periodically active landslides. Of these forms, 57% are exposed to the inflow of humid air-masses. They include four valley-slope slides, two forms in the initial sections of valleys and one hill-slope slide. They occupy a total of 4.5 hectares (only 4% of the total area modeled by gravity-driven processes). These forms recall weathered-rock slumps and are probably periodically active.

Type D - small stable slides. All forms classified as this type occur in the central part of the investigated area and occupy an area of about three hectares (3% of the total surface area of all slides). They are located on the slopes of small valleys and 80%

are exposed north or west. They were probably formed as small slides during intense precipitation and erosion periods. They are not currently active.

6.2. Types of landslide-creep forms

Type A1 - large, periodically active forms. They occupy an area of about 88.4 hectares (65% of the area modelled by the processes analyzed). This type includes thirteen forms located in the initial sections of valleys, nine valley-slope forms and four hill-slope forms. Of their total area, 65.4% is exposed to the humid air-masses from the north or west. These forms occur almost exclusively in the eastern part of the area investigated. Their origins are linked with high relief energy and local water circulation conditions. These forms are probably a recent development stage of old, wide slides.

Type B1 - large stable forms. The total area of this type of forms is about 41.8 hectares (30.6% of all the slide-creep-forms). 78.6% of their area is exposed north or west. They are not currently active. They are also strongly impacted by agricultural activities.

Type C1 - small, periodically active forms. Over 80% of their surface area is exposed north or west. They include four valley-slope forms, two initial-valley-section forms and one hill-slope form. They cover a total of about 2.7 hectares (2% of the total area of landslide-creep forms).

Type D1 - small stable forms. They include three valley-slope forms, two forms located in the initial sections of valleys and one hill-slope form. They occupy 3.5 hectares (3% of the total area of 52 forms analyzed) and their genesis is linked with local hydrological conditions. They are located in forest areas, which might have influenced their current stability.

The analysis of the spatial distribution of the types of forms described above allowed three zones which are intensively modelled by sliding and creeping processes to be identified. Their boundaries are determined by the valleys dissecting the marginal zone of the Foothills (see Fig. 1). These are:

Zone I - the area between the Uszwica river valley and the Stara Rzeka valley. It occupies about 1,345 hectares of which 142.7 hectares (10.6%) are modelled by the processes analyzed. In terms of area and number, the dominant forms are landslide-creep forms followed by landslides. Periodical activity dominates over stability (Tab. 5). This is linked with the dense network of valleys and the high energy of the area's relief.

Zone II - delimited by the Stara Rzeka valley and the Moszczenicki stream valley. It is the largest zone in this area (1,656.25 hectares) but sliding and creeping processes only model 58.9 hectares (3.6%) of its area. This area is strongly deforested and modified by human activities (agriculture, urban development). It includes 40 forms. The area and quantity of landslides and landslide-creep forms, and the balance between periodically active and stable forms are similar (Tab. 6).

Zone III - delimited by the valleys of Moszczenicki stream and the Raba river. Its area is about 290 hectares. The forms are genetically linked with the side erosion of

Tab. 5. Percentage contribution of landslides and landslide-creep forms in modelling Zone I.

Tab. 5. Udział osuwisk i form osuwiskowo-złaziskowych w modelowaniu rzeźby obszaru I.

	Landslides Osuwiska	Landslide-creep-forms Formy osuwiskowo-złaziskowe	Periodically active forms Formy okresowo aktywne	Stable forms Formy stabilne	Type A+A1 Typ A+A1	Type B+B1 Typ B+B1	Type C+C1 Typ C+C1
Number of forms Liczba form	10	29	28	11	26	9	4
Area , ha Obszar, ha	47.5	95.2	104.2	38.5	101.9	38.5	2.3
Percentage of total area Procent całkowitej powierzchni obszaru	3.5	7.1	7.7	2.9	7.5	2.8	0.3
Percentage of area modelled Procent powierzchni modelowanej	33.3	66.7	73	27	71.4	27	1.6

Tab. 6. Percentage contribution of landslides and landslide-creep forms in modelling Zone II.

Tab. 6. Udział osuwisk i form osuwiskowo-złaziskowych w modelowaniu rzeźby obszaru II.

	Landslides Osuwiska	Landslide-creep forms Formy osuwiskowo-złaziskowe	Periodically active forms Formy okresowo aktywne	Stable forms Formy stabilne	Type A+A1 Typ A+A1	Type B+B1 Typ B+B1	Type C+C1 Typ C+C1	Type D+D1 Typ D+D1
Number of forms Liczba form	21	20	20	21	9	11	10	10
Area , ha Obszar, ha	29.3	29.6	27.2	31.7	23	24.5	4.9	6.5
Percentage of total area Procent całkowitej powierzchni obszaru	1.8	1.8	1.7	1.9	1.4	1.5	0.3	0.4
Percentage of area modelled Procent powierzchni modelowanej	49.7	50.3	46.2	53.8	39	41.6	8.4	11

Tab. 7. Percentage contribution of land slides and landslide-creep forms in modelling Zone III.

Tab. 7. Udział osuwisk i form osuwiskowo-złaziskowych w modelowaniu rzeźby obszaru III.

	Landslides Osuwiska	Landslide-creep forms Formy osuwiskowo -złaziskowe	Periodically active forms Formy okresowo aktywne	Stable forms Formy stabilne	Type A+ A1 Typ A+ A1	Type B+ B1 Typ B+ B1
Number of forms Liczba form	9	3	11	1	11	1
Area , ha Obszar, ha	25.5	11.6	32.7	4.4	32.7	4.4
Percentage of total area Procent całkowitej powierzchni obszaru	8.8	4	11.3	1.5	11.3	1.5
Percentage of area modelled Procent powierzchni modelowanej	68.7	31.3	88.1	11.9	88.1	11.9

the Raba river. Their location is also related to the front of the Carpathian flysch overtrust. These forms occupy a total area of 37.1 hectares (12.8%). Despite the small size of this zone, sliding and creeping processes play a very important morphological role here. In terms of area and number, the dominant forms are landslides (over landslide-creep forms) and periodically active forms (over stable ones) (Tab. 7).

7. Role of gravity-driven processes in modelling the relief of the marginal zone of the Carpathian Foothills between the Raba and Uszwica rivers

The analysed area is intensively modelled by sliding and creeping (7.2% of the total area investigated).

- Large forms which are periodically active (Types A and A1) occupy an area of 157.6 hectares (4.8% of the area investigated).
- Large stable forms (Types B and B1) occupy an area of 67.4 hectares (2% of the area investigated).

– Small forms which are periodically active (Types C and C1) occupy an area of 7.2 hectares (0.2% of the area investigated).
– Small stable forms (Types D and D1) occupy an area of 6.5 hectares (0.2% of the area investigated).

Landslides cause fragmentation of the local relief. Creeping processes play a masking role or prepare the land for sliding. Present-day land sliding and creeping processes supply small amounts of material to the valley floor but they gradually lead to the retreat of slopes and the broadening of valleys. In the zones of strong degradation of the foothill hummocks by gravity-driven processes, very often the summit area is significantly narrowed. The borderline between the summit area and the slope thus becomes more evident. Due to the development of landslides and creeps the summits are divided into numerous, irregularly dome-shaped fragments. With time, the surface of the summit area may become lower.

The total area of landslides and landslide-creeps is 238.7 hectares, which accounts for 7.2% of the area investigated. In the literature, however, the average percentage share of landslides in modelling the surface of the Carpathians is assumed to be 4%. Thus it can be stated that land sliding and creeping processes play a more significant role in the formation of the relief in the Foothill area between the Raba and Uszwica rivers than in the flysch parts of the Carpathians. The microrelief of the forms is evidence of their complex genesis and multi-staged development. Regional environmental conditions create a predisposition for landslides to occur. Local diversity of the particular components of the environment influences their distribution, size and present-day activity.

The most significant morphogenetic role in the area investigated is played by large, periodically active forms. They occur mainly in zones I and III. These areas have a more sliding-related relief. Simultaneously they create optimum conditions for the generation of new forms and the activation of existing ones. Presently zones I and II are intensely modelled by mutually interacting processes of sliding and creeping. The most favourable conditions for further development occur on slopes located in the initial sections of the valleys. This is due to periodical, stream-related erosion and other phenomena. At the same time the forms created by sliding and creeping processes, due to their small depth and the character of mass displacements, can become active as often as several times a year (Kupczak, 1996).

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Typy osuwisk i ich rola w kształtowaniu rzeźby progowej części Pogórza Karpackiego między Rabą a Uszwicą

Streszczenie

Cechy litologiczne i strukturalne fliszu decydują o predyspozycjach osuwiskowych Karpat. Strefa progowa Pogórza Karpackiego, ze względu na kontrasty geologiczne i geomorfologiczne jest intensywnie modelowana przez procesy grawitacyjne.

Szczegółowe badania rozmieszczenia i współczesnego przekształcania osuwisk przeprowadzono na progu Pogórza Karpackiego między Rabą a Uszwicą (33 km^2). Starsze podłoże geologiczne obszaru stanowią utwory kredowo-trzeciorzędowe. Przykryte są one osadami wieku czwartorzędowego, wśród których najpowszechniejsze są utwory lessopodobne, o kilkunastometrowej miąższości. Obszar badań charakteryzuje się dojrzałą rzeźbą fluwialno-denudacyjną i od ponad 200 lat jest intensywnie użytkowany rolniczo.

Na obszarze badań występuje 40 osuwisk (o łącznej powierzchni 102,3 ha) i 52 formy osuwiskowo-złaziskowe (136,4 ha). Osuwiska posiadają wyraźnie wykształconą niszę oraz strefę akumulacji koluwialnej o znacznych deniwelacjach. Formy osuwiskowo-złaziskowe są duże, lecz nie posiadają wykształconej niszy (tab. 3). Współcześnie są one modelowane przez współdziałające procesy osuwania i spełzywania (ryc. 1).

Wszystkie analizowane formy zlokalizowane są na zboczach dolin, w początkowych ich odcinkach lub na stokach (ryc. 1, 2, tab. 1). Ekspozycja form wpływa wyraźnie na ich liczbę i współczesne przekształcanie. Nie różnicuje natomiast ich morfometrii (ryc. 3, tab. 2).

Wynikiem badań jest typologia osuwisk i form osuwiskowo-złaziskowych oparta na wykształceniu form, ich wielkości oraz współczesnej aktywności. Przestrzenne rozmieszczenie wyróżnionych typów form pozwoliło na charakterystykę trzech obszarów intensywnie modelowanych przez procesy grawitacyjne:

- obszar I - o powierzchni 1345 ha, w 10,6% modelowany przez osuwanie i spełzywanie,
- obszar II - o powierzchni 1656,25 ha, w 3,6% modelowany przez osuwanie i spełzywanie,
- obszar III - o powierzchni 290 ha w 12,8% modelowany przez osuwanie i spełzywanie.

Określono współczesną aktywność procesów grawitacyjnych oraz ich rolę w modelowaniu rzeźby progu Pogórza Karpackiego. Formy okresowo aktywne, o wyraźnej mikrorzeźbie osuwiskowej, zajmują powierzchnię 164,1 ha, w tym typowe osuwiska - 73,7 ha. Formy stabilne o dojrzałej rzeźbie osuwiskowej obejmują 76,6 ha, w tym osuwiska - 28,6 ha.

Łączna powierzchnia osuwisk i form osuwiskowo-złaziskowych stanowi 7,2% powierzchni obszaru objętego badaniami. Rola procesów grawitacyjnych w modelowaniu rzeźby progu Pogórza Karpackiego między Rabą a Uszwicą przejawia się w:
– rozczłonkowaniu rzeźby obszaru i ukierunkowaniu jej dalszego rozwoju,
– cofaniu zboczy i poszerzaniu dolin,
– zwężeniu powierzchni wierzchowinowej, jej rozczłonkowaniu i obniżeniu,
– dostawie materiału do den dolin.

Mikrorzeźba form dowodzi ich złożonej genezy i wieloetapowego rozwoju. Lokalne zróżnicowanie budowy geologicznej, rzeźby, warunków klimatycznych oraz sposób użytkowania obszaru wpływają na rozmieszczenie, rozmiary i współczesną aktywność form.