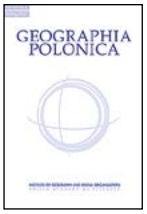

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CYLOWA ZERWA LANDSLIDE – DEBRIS FLOW FORMS ON MOUNT BABIA GÓRA (1725) AND THEIR DEVELOPMENT OVER THE LAST CA. 150 YEARS, WESTERN CARPATHIANS

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Abstract

Cylowa Zerwa landslide – debris flow located on the northern slope of Mt. Babia Góra (1725 m a.s.l.) within the 400 m wide altitude interval (1430-1024 m a.s.l.) is a knowable object which however has not been sufficiently noticed in geomorphological research. This paper, based on geomorphological, geological and dendrochronological investigations, as well as LiDAR data analysis, develops the following issues which describe the functioning of this object during the last ca. 150 years: Cylowa Zerwa in the gravity induced mass movements system of Mt. Babia Góra; relief of the landslide – debris flow and surrounding areas; stages of changes in limit and relief of the mass movement area during the last 150 years; relief elements of the Cylowa Zerwa which are related to debris flow; relationship between dates of the Cylowa Zerwa activation with annual spruce increments. The Cylowa Zerwa, as the only one among Mt. Babia Góra landslides studied, is distinguished by a clear bipartite relief – the upper segment is represented by rock packages, whereas landforms of the middle and lower segments are similar to those originated in the conditions of debris flow. The Cylowa Zerwa landslide – debris flow shows significant education values and it is a remarkable geotourist object.

Key words

Mt. Babia Góra • Western Flysch Carpathians • homoclinal ridge • structural relief • landslide • debris flow • damages in forest • disturbances in touristic movement • geotourism

Introduction

In the investigations of Flysch Carpathians relief an attention has often been paid to the extend and dynamics of landslides of different types in relations to morphology and morphometry of slopes as well as to bedrock lithology and tectonics (Ondrášik, 2002; Ziętara, 2004; Margielewski, 2006, 2009; Jankowski & Margielewski, 2014, 2021; Mrozek et al., 2014; Pánek et al., 2019; Březný & Pánek, 2017; Jankowski et al., 2019; Kłapyta, 2020; Łajczak, 2022a,b). The landslides in this area usually do not show any symptoms of mobility, but some activate so often that can locally cause large economic damages. In the area above agricultural-forest boundary, damages caused by landslides include only forests, and only locally roads and tourist infrastructure. On the other hand, the results of landslide activations in the areas under strict nature protection have not been generally known. Investigations of homoclinal ridges, especially those of large denivelations (where it is possible to show differences between the relief and landslide dynamics within scarp and penestructural slopes) seem to be worthy of note. Such investigations have started recently on Mount Babia Góra (1725 m a.s.l.) which is the highest flysch ridge in the Western Carpathians (Łajczak et al., 2014; Kłapyta, 2020; Łajczak, 2022a,b). They refer to investigations on structural relief of this massif which have been carried out there since the 1960s (Książkiewicz, 1963, 1971, 1983; Niemirowski, 1963, 1983; Alexandrowicz, 1978, 2004; Łajczak, 1998, 2013, 2014; Wójcik et al., 2010; Jankowski & Margielewski, 2021; Jankowski, 2022).

The object of investigation is the Cylowa Zerwa gravity induced landforms located on the northern slope of Mt. Babia Góra within the boundaries of the Babia Góra National Park (Figs. 1c, 2). Special attention was paid to

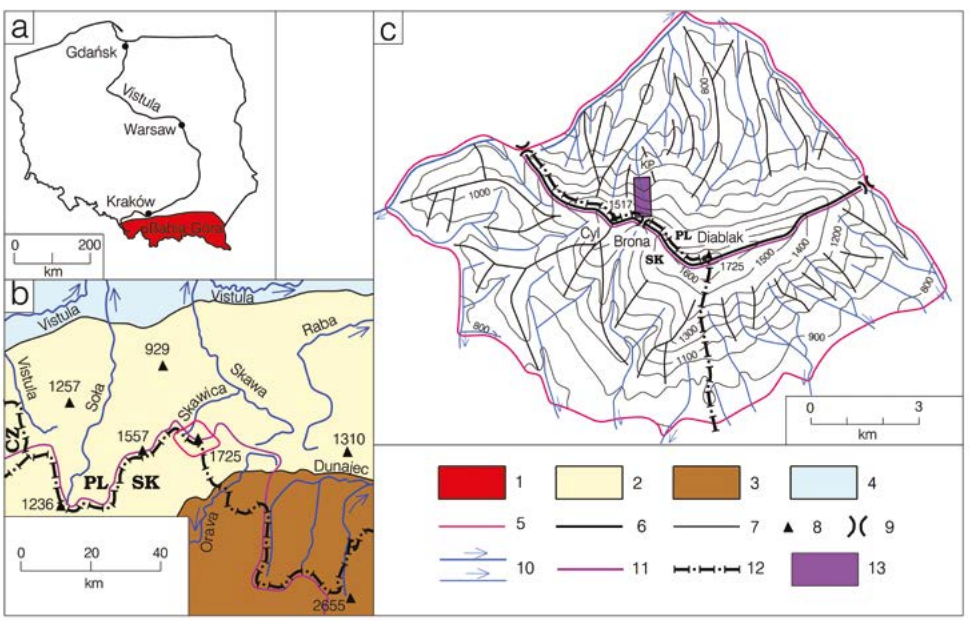

Figure 1. Location of Mt. Babia Góra: a – in Poland; b – in western part of the Polish Carpathians; c – morphological sketch of Mt. Babia Góra. 1 – area of the Carpathians in Poland; 2 – Outer (Flysch) Carpathians; 3 – Inner Carpathians; 4 – Subcarpathian Basins; 5 – border of Mt. Babia Góra massif; 6 – axis of ridge of Mt. Babia Góra; 7 – axes of side ridges of Mt. Babia Góra; 8 – summit; 9 – pass; 10 – river, stream; 11 – Main European Watershed; 12 – Polish-Slovak and Polish-Czech national borders (PL –Poland, SK – Slovakia, CZ – Czech Republic); 13 – location of the Cylowa Zerwa landslide – debris flow

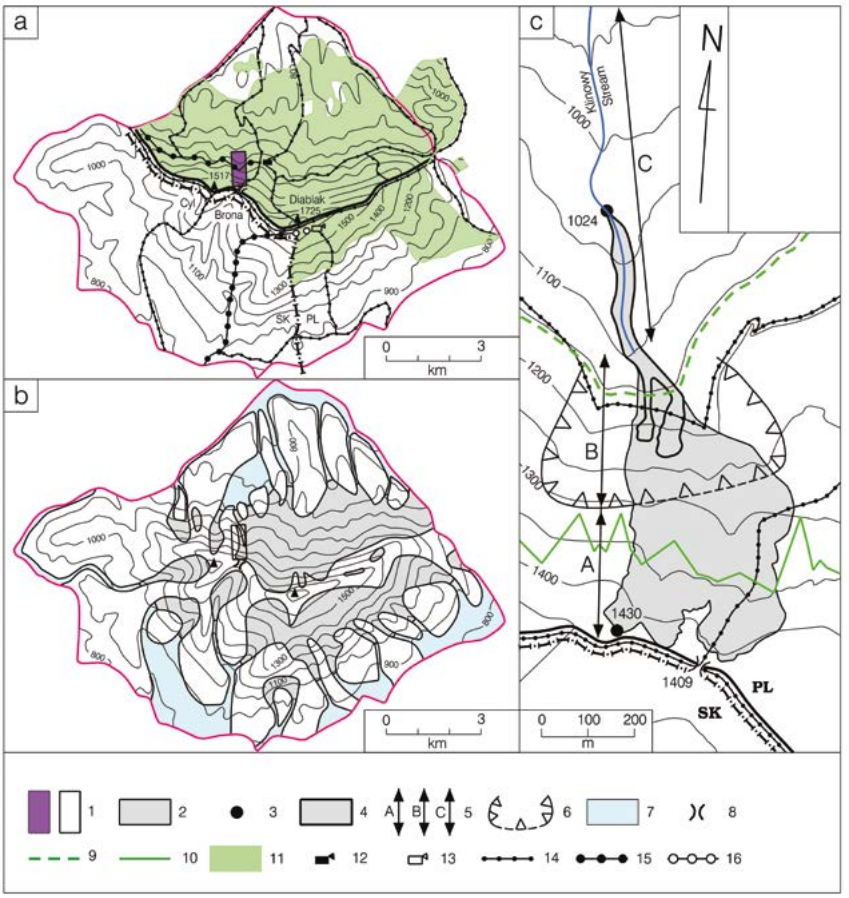

Figure 2. Location of the Cylowa Zerwa landslide – debris flow in Mt. Babia Góra: a – in the massif; b – on the background of deep-seated landslides and alluvia limit in the massif (according to Łajczak 2016); c – limit of the Cylowa Zerwa. 1 – location of the Cylowa Zerwa; 2 – extend of the Cylowa Zerwa landslide – debris flow and other landslides; 3 – the highest and the lowest points of the Cylowa Zerwa (altitudes in m a.s.l. are marked); 4 – active part of the Cylowa Zerwa after 1868; 5 – slope segments occupied by the Cylowa Zerwa landslide – debris flow: A – slope modelled by deep-seated landslide, B – headwater area of the Klinowy Stream, C – V-shaped valley of the Klinowy Stream; 6 – extend of the Klinowy Stream headwater area; 7 – alluvia; 8 – the Brona Pass (1409); upper limit of: 9 – lower montane forest belt, 10 – upper montane forest belt; 11 – the Babia Góra National Park; 12 – tourist shelter; 13 – former tourist shelter; 14 – tourist trail; 15 – trail of the largest tourist traffic until 1939; 16 – segment of non-used tourist trail. For explanations of other symbols see Fig. 1

the youngest part of the landslide, which has activated since 1868.

Study site

Mt. Babia Góra (1725 m a.s.l.) is the highest massif in the Outer (Flysch) Western Carpathians. It is situated in the borderland of Poland and Slovakia in the Beskid Żywiecki mesoregion (Fig. 1b) (Starkel, 1972; Kondracki, 1998), at the line of Main European Watershed separating the Baltic Sea and the Black Sea drainage basins, and represents the source area of tributaries of the Skawica and the Orava rivers (the Vistula and the Danube river basins respectively). The main – homoclinal ridge

of Mt. Babia Góra is 11.3 km long and shows W-E course. Its N-S profile is asymmetric: the northern slope of concave profile is steeper than the southern penestructural slope of convex-concave profile. In the ridge of Mt. Babia Góra there are two culminations: Diablak (1725 m a.s.l.) and Cyl (1517 m a.s.l.) separated by Brona Pass (1409 m a.s.l.). The main ridge is connected with lower side ridges which are separated by valleys of convergent pattern in the northern part of the massif, and divergent pattern in the southern part. Along the axis of the main ridge, from the west to the highest culmination, and further downslope to the south of the massif, there is Polish-Slovak boundary. The area of Mt. Babia Góra massif is 74.81 km^2, including 28.28 km^2 of the northern slope and 46.53 km^2 of the southern slope. 40% of the massif is located within the boundaries of the Babia Góra National Park (Fig. 2a).

The upper part of Mt. Babia Góra massif is built of Magura sandstones beds (age: middle and upper Eocen) dipping homoclinally to the south. Lower parts of the northern slopes and their foothills are built of older Flysch formations, mainly Hieroglyphic beds (age: middle Eocen) formed mainly of thin-bedded flysch (Jankowski, 2022). There are following vegetation belts on Mt Babia Góra: lower montane forest (to 1150 m a.s.l.), upper montane forest (to 1370 m a.s.l.), dwarf mountain pine (to 1650 m a.s.l.), and higher alpine meadow (Celiński & Wojterski, 1983; Czajka et al., 2015). Mt. Babia Góra is a popular tourist destination. There are numerous tourist trails which lead to the mountain shelter located on the northern slope (in operation since 1906) and to the massif culmination, and to another mountain shelter (in operation in the period 1905-1939) located at the massif culmination on the southern slope (Płaza, 2004; Fig. 2a).

The Cylowa Zerwa landslide is located at the northern side of the Brona Pass and includes a precipitous steep slope, the lower part of which represents a headwater area of the Klinowy Stream. The landslide penetrates a narrow bottom of V-shaped valley of this stream (Fig. 2c). The landslide is located at the altitude 1430-1024 m a.s.l. within the following vegetation belts: lower montane forest, upper montane forest, dwarf mountain pine. It is located within the boundaries of the Babia Góra National Park (Fig. 2a). In the mid part of the landslide there is a contact of the Magura sandstones with the Hieroglyphic beds. Two tourist trails go across the landslide, one of them goes across its active part (Fig. 2c).

State of research of the Cylowa Zerwa

The Cylowa Zerwa landslide was for the first time mentioned by Zapałowicz (1880), however its name and detailed location was not quoted. That author paid attention to the first known activation of this landslide in 1868. Activation of the Cylowa Zerwa landslide was mentioned also by other authors (Midowicz, 1930; Niemirowski, 1963). More and more detailed descriptions of this object have started to appear in unpublished works and published papers for the last 50 years. An attention should be paid to a non-published geological expert report (Bober & Oszczypko, 1973) which includes, among others, the map and cross-section of the active part of the landslide with lithology details of the bedrock. Some papers (Niemirowski, 1983; Łajczak, 1995; Bajgier-Kowalska, 2002; Ziętara, 2004) contain the description of the landslide topographic features, whereas newer papers (Kłapyta, 2020; Łajczak, 2022a,b) contain also preliminary cartographic picture of the object. Stages of landslide development after 1868 were pointed by Łajczak (2008). In geological-tourist guidebook of the Babia Góra National Park (Wójcik et al., 2010) this landslide was unmentioned. In many descriptions of the Cylowa Zerwa landslide its name either was not mentioned or it was referred to as "landslide in the area of Borsucze Skały" (Niemirowski, 1963, 1983; Bober & Oszczypko, 1973; Bajgier-Kowalska, 2002; Ziętara,

2004). This name is not consistent with local toponymics, because rockfalls called Borsucze Skały are located 0.5 km to the west of the site.

The name of the landslide "Cylowa Zerwa", which is consistent with nomenclature applied in the Babia Góra National Park, was introduced by Łajczak and it is currently used (Łajczak, 2008, 2016, 2022a,b). It should be stressed however, that the extend of the Cylowa Zerwa landslide is usually associated by naturalists and tourists exclusively with its most active part visible from the tourist trail which goes across the landslide – called in Polish "Górny Płaj", 1180 m a.s.l. This part of the Cylowa Zerwa landslide goes up the slope to the limit of two semicircular scarps remodelled in the years 2000-2004 (1200-1230 m a.s.l.) and down the slope to the middle section of the elongated landslide track of debris slide (1150 m a.s.l.). The majority of the area of the Cylowa Zerwa landslide is not visible from the mentioned tourist trail. The highest limit of the landslide reaches the altitude 1430 m a.s.l. on the slope west of the Brona Pass (1409 m a.s.l.). Also the lower part of the landslide, reaching the altitude of 1024 m a.s.l., is not visible from that tourist trail (Fig. 2c).

Despite the fact, that geologists and geomorphologists have indicated the importance for science of the Cylowa Zerwa landslide for the last 50 years (Bober & Oszczypko, 1973; Niemirowski, 1983; Łajczak, 1995, 1998, 2008, 2022a,b; Bajgier-Kowalska, 2002; Ziętara, 2004; Kłapyta, 2020), any detailed geomorphological studies have been carried out.

The aim of the paper is the explanation of the following issues concerning the Cylowa Zerwa landslide, the most of which have not been the aim of any other research so far: (1) description of the Cylowa Zerwa landslide at the background of other landslides in Mt. Babia Góra, (2) analysis the relief of the landslide and its surrounding, (3) dynamics of the landslide during the last ca. 150 years and changes in its relief, (4) active part of the Cylowa Zerwa – a debris slide *sensu* Dikau et al. (1996) or a debris flow, (5) correlation of dates of landslide activation with annual growth of trees, (6) prognosis of landslide development.

Materials and methods

The following materials were applied in the work: (a) investigation results of the Cylowa Zerwa landslide which included, among others, mapping of morphologically active part of the object in 1976, 1997 and 2005 (Łajczak, 1998, 2008, 2016, 2022a,b), (b) information from quoted papers, (c) archival materials of the Babia Góra National Park concerning the history of forest management and changes in tree stands adjacent to the landslide since the 1850s, as well as history of Mt. Babia Góra tourism, (d) photos of the active part of the landslide showing its state since 1962 (photographs from the collections of the Babia Góra National Park and A. Łajczak).

Increment cores using Pressler`s corer were sampled from 8 trees (Norway spruce – *Picea abies* L. H.Karst) which grow at the eastern edge of the lower part of the landslide. The cores became polished and dendrochronologically cross-dated using pointer years (Schweingruber et al., 1990; Yamaguchi 1991). Good pointer years for a spruce in Mt. Babia Góra in the 20th century include 1980 (narrow ring), 1933 (narrow late wood), 1912 (light late wood of small density), followed by a narrow tree-ring of 1913 (Zielonka, 2006). The age of the investigated trees was estimated basing on the first tree-ring (the closest to the pith) plus the number of years necessary to obtain the height where the tree was sampled (Zielonka, 2006). Reductions and releases were established on dated samples. A reduction was assumed as a sudden tree-ring width decrease lasting for at least 10 years. Such changes in radial growth dynamics should be interpreted as the result of a tree damage (its root system, live tissues of a stem, or considerable reduction of assimilatory organs due to e.g. damage of branches). Another element determined in the samples included release, i.e. sudden increase in the tree-ring width. Releases

are used to date disturbances of different nature caused by the decrease of competition which occurs when the surrounding trees are eliminated (Nowacki & Abrams, 1997). Both the depressions and releases represent extra-climatic reaction of trees to rapid changes in the environment including those of geomorphological nature. Additionally, during the analysis of wood samples the attention was paid to the presence of traumatic resin ducts which are produced as a reaction to stress caused by deterioration of growth conditions (Schweingruber, 1989).

In the assessment of the relief of the Cylowa Zerwa landslide both the qualitative and quantitative methods were used including LiDAR data. Basing on a LiDAR image a contour-line map with 1 m interval of the landslide and its surrounding was generated. It was the basis to verify the limits of landforms which were earlier determined during geomorphological mapping at the scale of 1:5000. This way, the limit and relative height of landforms within the study site (scarps, colluvial tongues/lobes, channels, torrential cones, levees) and in its surrounding (ridge flattenings, ridge and slope trenches, slopes of "smooth" morphology, alluvial fans, edges of erosional cuttings, rocky channels, waterfall steps) were established with accuracy of 1.0 m. Basing on six transversal profiles of the lower part of headwater area and the upper section of the Klinowy Stream valley and with application of hillside slope extrapolation, a thickness of colluvial deposits was estimated in the lower part of the landslide of convex transversal profile. In the reconstruction of transversal profile of the fossil part of valley bottom, two visible transversal profiles of the narrow bottom of the valley directly below the landslide front were included.

Results

The Cylowa Zerwa at the background of Mt. Babia Góra landslides

Deep-seated landslides predominate on Mt. Babia Góra slopes. They cover approximately half of the area of slopes built of Magura sandstones (Łajczak, 2016; Kłapyta, 2020). The remaining area of this part of the massif includes slopes of "smooth" morphology (uniform dip of slopes on large area) covered by rock-debris of periglacial origin as well as slopes with rocky walls dissected by couloirs, debris and torrential cones, and landforms connected with debris flows. In the western part of the massif of Mt. Babia Góra, isolated landslides predominate, whereas in its central and eastern parts there are vast landslides of complex type, which are typical for Mt. Babia Góra (Ziętara, 2004) and which may cover 600 m high altitude interval on slopes (Fig. 2b). Colluvia occupy the area from the slope to the valley bottom, penetrating these later as a lobes, where they gradually transform into alluvia. The bottoms of headwater areas and valleys which dismember lower parts of slopes (only above sections of deepened valleys with rocky channels) are lined on its entire length first by debris-clay material which built valley landslides, and then by coarse-clast alluvia.

The Klinowy Stream Valley (where the Cylowa Zerwa landslide occurs), is the only one among the valleys dismembering the lower parts of slopes of Mt. Babia Góra, where there is no colluvial cover in the lower 0.5 km long section (between 900 and 1024 m a.s.l.) (Fig. 2b,c). Above 1024 m a.s.l. it is filled by the tongue of the Cylowa Zerwa landslide. Below 900 m a.s.l. an alluvial fan from the adjacent valley enters it. Between these altitude the valley bottom is narrow with rocky channel and several meter high waterfall steps. These features of the Klinowy Stream valley as compared to other valleys in the massif indicate relatively small length of the lower segment of the Cylowa Zerwa landslide. The feature which distinguishes this landslide among other landslides on Mt. Babia Góra includes also documented changes in the relief of its middle and lower segments which have occurred during the last ca. 150 years (Łajczak, 2008). Such changes have not been determined recently in other landslides on Mt. Babia Góra.

Relief of the mass movement area and its surrounding

Three segments of the Cylowa Zerwa landslide were distinguished in the investigations, which differ in terms of their relief, slope gradient and colluvium thickness (Figs. 2c, 3, 4, 5). The landslide area is 16.8 ha, including 9.4 ha belonging to the segment (A), 6.1 ha to segment (B) and 1.3 ha to segment (C). The length of the whole landslide is 1100 m, including 360 m, 390 m and 350 m respectively. The active part of the landslide during the last ca. 150 years covers 2.6 ha, i.e. 15% of its total area, however its length is 550 m, which makes as much as 55% of the total length of the landslide (Figs. 3, 4).

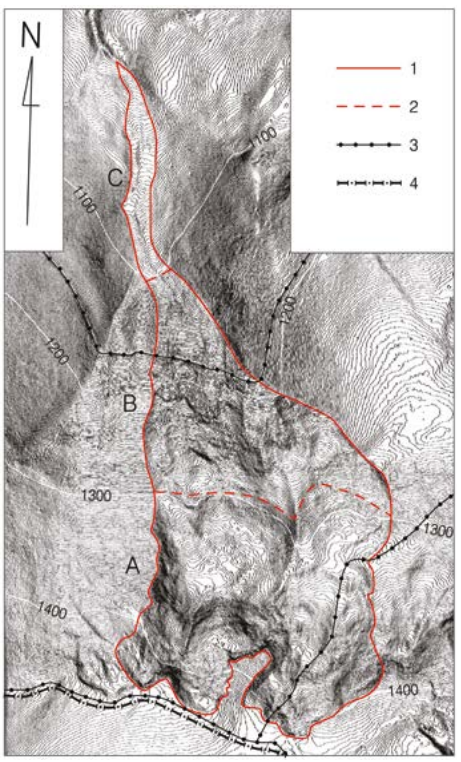

Figure 3. The boundary of the Cylowa Zerwa landslide – debris flow shown on contour line background (every 1 m) (based on LiDAR image). 1 – limit of the Cylowa Zerwa – debris flow; 2 – boundary between segments (A) and (B), and between (B) and (C) of the object; 3 – tourist trail "Górny Płaj"; 4 – Polish-Slovak national border

Above 1300 m a.s.l. up to the slope boundary with plateau at the altitude 1409-1430 m a.s.l., there is the upper segment (A) of the landslide. Its main feature are slumped (backwardly rotated) rock blocks covered by debris colluvial material of unknow depth. This part of the slope shows step-like profile of an average slope dip of 37°, ranging from several degrees to 70° (Figs. 4, 5). Landslide depressions are occupied by landslide fens, and in one of them there is a landslide tiny lake (Mały Staw lake, 1307 m a.s.l.). Rock packages occur in the landslide depression bordered by up to 20 m high precipitous escarpments. Outside the landslide scarps there are up to 10 m deep slope trenches, as well as slope parts of "smooth" morphology lined by debris material of periglacial origin (Figs. 3, 4). The upper edge of the landslide scarps, just at the border with the plateau, shows a winding course and it is adjacent to ridge flattenings of step-like pattern. The occurrence of the slope part of "smooth" morphology (i.e. a slope part of older relief) in the neighbourhood of this part of the landslide scarps prooves progressive recession of the Cylowa Zerwa landslide up the slope. There is no information about contemporary dynamics of the upper part of the segment (A) of this landslide.

In the contact zone of the Magura sandstones with underlying the Hieroglyphic beds there is a headwater area of the Klinowy Stream. Its altitude range is from 1150 to 1300 m a.s.l. Half of the headwater area is occupied by the segment (B) of the Cylowa Zerwa landslide, where slope gradients are larger than in the segment (A) and increase with altitude from 32° do 60°. The average slope gradient is 42°. This segment of the landslide is built of debris colluvia of visible depth up to 5 m, where diameter of sandstone blocks is smaller than in segment (A) and does not exceed 3 m. The morphology of segment (B) of the landslide is less diversified that in segment (A). Relief features include low colluvial tongues and up to 5 m high isolated rocky scarps and also up to 3 m high scarps visible along the whole length of this segment

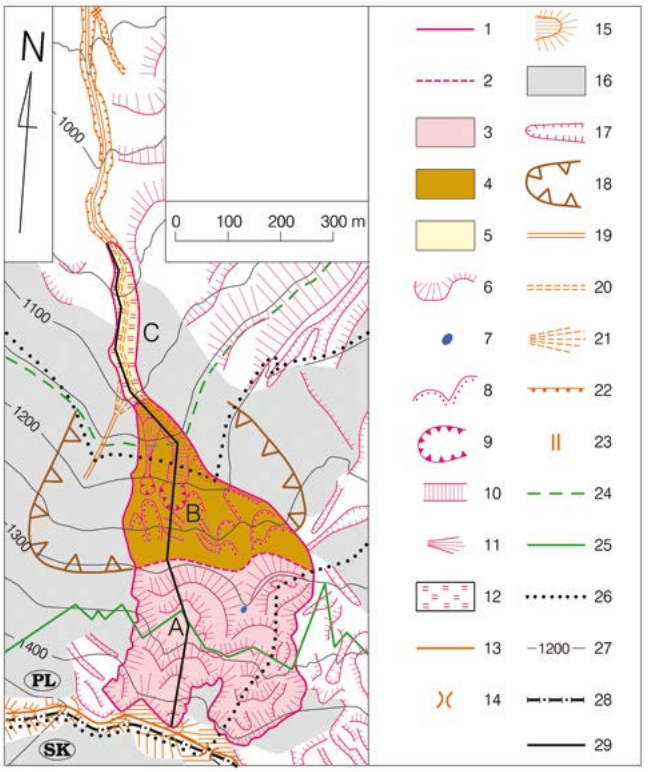

Figure 4. Morphological sketch of the Cylowa Zerwa landslide – debris flow. 1 – limit of the object; 2 – boundary between segments of the object; the segments: 3 – (A), 4 – (B), 5 – (C); 6 – scarp; 7 – landslide tiny lake; 8 – colluvial lobe; 9 – scarps in segment (B); 10 – landslide channel in segment (B); 11 – torrential cone; 12 – levee; 13 – axis of ridge; 14 – the Brona Pass (1409 m a.s.l.); 15 – ridge flattening; 16 – slope of "smooth" morphology; 17 – ridge or slope trench; 18 – the Klinowy Stream headwater area; 19 – erosional cutting; 20 – erosional cutting covered by colluvia; 21 – alluvial fan; 22 – edge of erosional cutting in the bottom of the Klinowy Stream, which rejuvenated its relief; 23 – the highest waterfall step; upper limit of: 24 – lower montane forest belt, 25 – upper montane forest belt; 26 – tourist trail; 27 – contour line; 28 – Polish-Slovak national border (PL – Poland, SK – Slovakia); 29 – course of landslide – debris flow profile shown in Figs. 5, 8

on the eastern and western boundaries of the landslide. These scarps delimit the zone of colluvium deposition transported from segment (A) of the landslide (Fig. 6). The slopes of headwater area outside the landslide limit, as well as neighbouring parts of the northern slope of Mt. Babia Góra, are covered by finer debris material of periglacial origin. Its thickness does not exceed 3 m. The slopes of "smooth" morphology, despite their gradients reaching 40°, may be assumed as continuation of slope parts adjacent to segment (A) of the landslide. Segment (B) of the Cylowa Zerwa landslide is assumed as younger than segment (A). It is an element of slope morphology superimposed on older relief of headwater area of the Klinowy Stream (Fig. 4).

A lower part of the segment (B) of the Cylowa zerwa landslide and the whole segment (C) contain elements of younger relief, which were formed during recurrent renewals of the landslide activity since 1868 (Łajczak, 2008) (Figs. 4, 5). In segment (B) of the landslide at the altitude 1200-1230 m a.s.l. there are two scarps, where the Magura sandstones are exposed under 2-5 m high escarpments

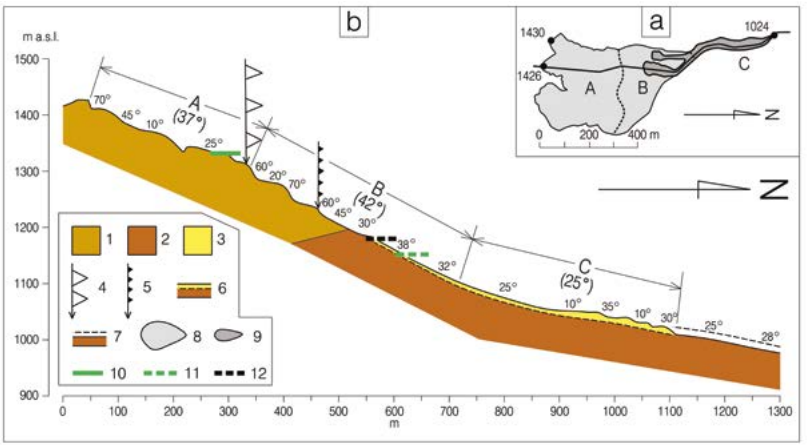

Figure 5. Longitudinal profile of the Cylowa Zerwa landslide – debris flow (simplified version when compared with the text). a – location of the profile; b – differentiation of slope dip in segments (A), (B), (C). Landslide substratum: 1 – Magura sandstones, 2 – Hieroglyphic beds; 3 – colluvia; altitude ranges: 4 – the Klinowy Stream headwater area, 5 – the larger landslide scarp in segment (B); 6 – bottom of headwater area and a narrow erosional cutting in the valley covered with colluvial material; 7 – bottom of a narrow erosional cutting and higher located valley bottom down of landslide tongue; 8 – landslide – debris flow extent; 9 – extend of the rejuvenated part of the object; 10 – timberline; 11 – limit of lower montane forest belt; 12 – tourist trail "Górny Płaj"

(Fig. 7). Layers of Magura sandstones are dipping homoclinally to the south at the angle of 20°. These are thick-bedded, usually medium- and fine-grained sandstones. Their over 2 m thick beds are separated by thin insertions of clayey and marly shales. In the substratum of the lower located part of the landslide (a lower part of the segment B and the whole segment C), the Hieroglyphic beds are cropping out. These represent complex of thin bedded and fine-grained sandstones which regularly interbed with clayey shales (Bober & Oszczypko, 1973). Slope gradients within the larger landslide scarp decrease from 60° to 45°, in the lower located landslide track decrease to 30°, and again increase below the tourist trail "Górny Płaj" to 38° (Fig. 5). The landslide track is 40-50 m wide and 200 m long and at the altitude 1150 m a.s.l. it turns left. At the altitude 1110 m a.s.l. it transforms into a 30-50 m wide landslide tongue which fills the bottom of the upper section of the Klinowy Stream Valley. The second scarp, located at the west, is smaller. The landslide track is only 5-7 m wide and its dip near the tourist trail "Górny Płaj" exceeds 40°. In this

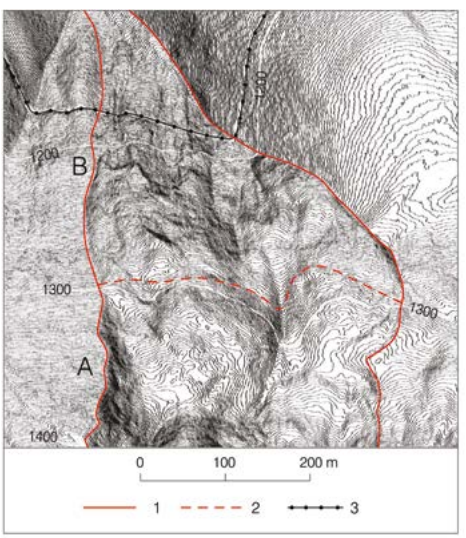

Figure 6. The western and the eastern boundaries of the segment (B) of the Cylowa Zerwa landslide – debris flow visible on the contour-line background (every 1 m) (based on LiDAR image). Scarps at the indicated limits of this segment of the object are clearly visible. 1 – the Cylowa Zerwa landslide – debris flow limit; 2 – boundary between segments (A) and (B); 3 – tourist trail "Górny Płaj"

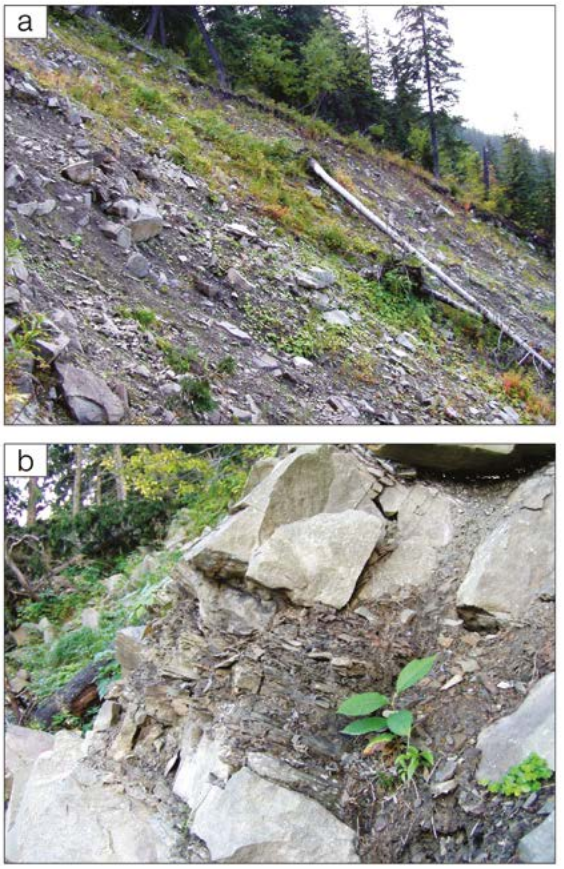

Figure 7. The larger scarp of the Cylowa Zerwa landslide – debris flow: a – view on the uppermost part of the scarp (1230 m a.s.l.), b – outcrops of layers of the Magura sandstones and insertions of shales

section of the landslide track, the fronts of the Magura sandstones beds are exposed, where a small waterfall (Płaczliwa Skała – Crying Rock) appears after rainfalls. Below this 70 m long landslide track, a torrential cone is visible. It is 80 m long and its dip is 25°. At the altitude 1125-1140 m a.s.l. it joins the larger landslide track.

The tongue of the Cylowa Zerwa landslide – segment (C) shows convex transversal profile, and below 1070 m a.s.l. a step-like longitudinal profile (Figs. 5, 8). The slope gradient of landslide tongue decreases from 25° to 10°, however in the lower part it locally reaches 30°. The front of the landslide tongue penetrates into a narrow erosional cutting in the bottom of the Klinowy Stream Valley. Morphology of this erosional cutting does not show any changes within the 500 m long section below the landslide front (Fig. 4), therefore it should be assumed that continuation of this landform – of fossil character – occurs below the landslide tongue (C), and also under lower part of the segment (B) of the landslide. This assumption results from the analysis of transversal profiles of the Klinowy Stream Valley occupied by the landslide (Fig. 8). Steep slopes of the valley are adjacent to the landslide tongue of convex transversal profile; the extrapolation of the course of slopes makes it possible to estimate the thickness of colluvial deposits in the profiles II-V to over 10 m. This fragment of the landslide between the middle section of the larger

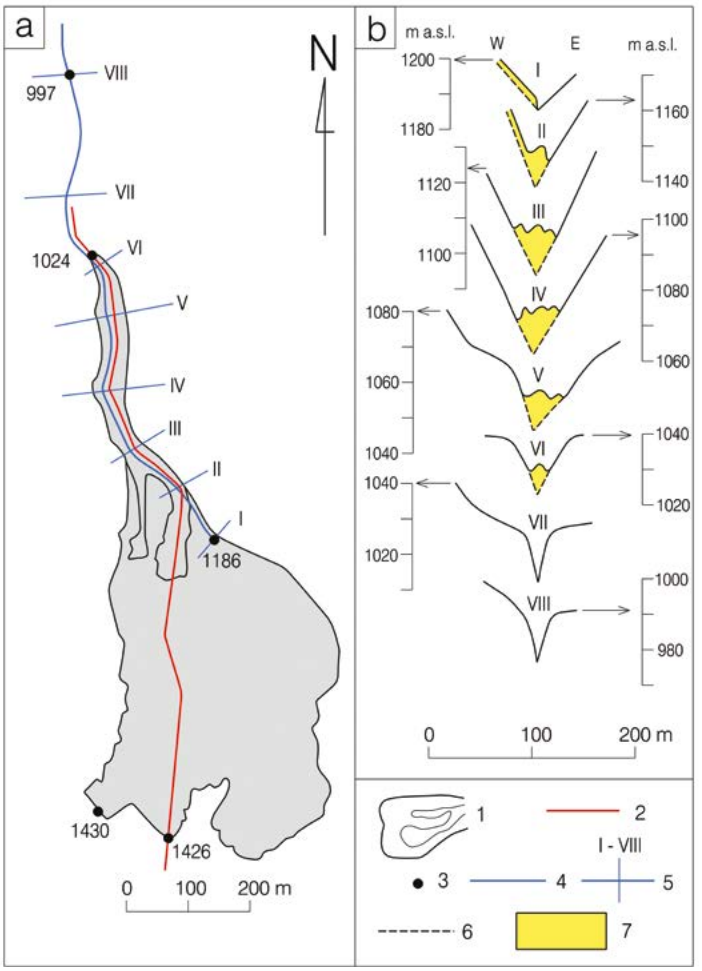

Figure 8. Transversal profiles across the lower part of headwater area and upper part of the Klinowy Stream valley, within the limit of the Cylowa Zerwa landslide – debris flow (profiles I-VI) and below the landslide tongue (profiles VII, VIII). Profiles were prepared basing on LiDAR data. a – profile location, b – profile. 1 – limit of the landslide and its active part (debris flow); 2 – the course of profile shown in Figs. 4, 5; 3 – the highest and the lowest located points within the landslide – debris flow (altitude in m a.s.l.); 4 – upper section of the Klinowy Stream; 5 – location of profile; 6 – probable profile of slopes under the colluvium surface; 7 – colluvia

landslide channel and the lower part of the landslide tongue represents the area of the most intensive colluvial deposition in the active part of the Cylowa Zerwa landslide.

Changes in the extend and relief of the landslide during the last ca. 150 years

The obtained information sources make it possible to determine changes in the extend and relief of the Cylowa Zerwa landslide only in the segments (B) and (C) since 1868.

The information given by Zapałowicz (1880) concerning the sliding of colluvia in the place interpreted as the Cylowa Zerwa, which was obtained from shepherds during his botanical research on Mt. Babia Góra in the 1870s, makes it possible to explain the course of the segment (B) formation at the end of May 1868. Zapałowicz description

of the Cylowa Zerwa contains the following statement of geomorphological nature: "*the slumped colluvia earlier had formed a part of transversal ridge*" (this ridge is represented by backwardly slumped rock packages located in the lower part of the segment (A) of the landslide, Figs. 3, 4); "*the colluvia sliding must have occurred quickly"; "the layer of activated colluvia flown around as a dense liquid buried trees everywhere".* Colluvial deposits which covered a wide zone of the slope must have been derived from the segment (A) of the landslide. It is difficult to explain the intensity of this process exclusively by rainfalls. It is possible that sliding of large masses of colluvia along the slope influenced by local dislocation of rock packages in the segment (A) of the landslide, was triggered by earthquake. In the specification of earthquakes in the Polish Carpathians there is no such date of seismic tremor (Hojny-Kołoś, 1972) which does not mean however, that such event at that time did not occur on Mt. Babia Góra. A possible occurrence of an earthquake in this massif at the time suggested by Zapałowicz is indicated by an information inserted in the newspaper Czas (Time) published in Kraków in 1868 about a loud bang which was heard in Zawoja centre located over 10 km of Mt. Babia Góra culmination. It was caused by sliding of large rock masses (Magura sandstones) on the northern slope in the place which is called Urwane (Torn) since that time (Łajczak, 1995). This episode was mentioned by Zapałowicz (1880) and Midowicz (1930).

Information of H. Zapałowicz about the "spill" of colluvial material during the mentioned episode in the place of the Cylowa Zerwa landslide explain the origin of convex morphological landforms at the edge of the segment (B) of the landslide and also origin of numerous colluvial lobes (Figs. 3, 4, 6) within the headwater area of the Klinowy Stream. This part of the slope shown in the LiDAR image (Fig. 6) indicated the way of material transportation not as a slide but rather debris flow. The thickness of these slope deposits does not exceed 5 m and usually it is in the range 2-3 m. Deposition of the material derived from segment (A) of the landslide, taking into account large slope gradient of headwater area exceeding 30° (Fig. 4), must have included also the valley bottom of the upper section of the Klinowy Stream, i.e. the whole segment (C). The probable limit of the Cylowa Zerwa landslide before the episode of May 1868, is shown in Fig. 9a, and directly after the episode is shown in Fig. 9b. Elements of the relief still visible in the segment (B) of the landslide which originated in 1868 include mentioned before long scarps and colluvial lobes. Small fragments of segment (B) and most part of segment (C) of the landslide were remodelled during succeeding stages of the Cylowa Zerwa activation.

In the first forest inventory of the Babia Góra National Park dated to 1.10.1961 (Archive of the Babia Góra NP) there is information of the occurrence of 40-50 year old mountain ash bushes on the area of 0.47 ha in the eastern part of the segment (B) of the Cylowa Zerwa at the altitude 1130-1170 m a.s.l. (below the tourist trail "Górny Płaj"). Mountain ash as a photophilous species must has invaded the part of the landslide where the forest had been destroyed due to the activation of the Cylowa Zerwa. Taking into account the time after which a mountain ash may invade freshly deposited material, i.e. 5 years, the second stage of the Cylowa Zerwa activation may be related about 1905. In 1961 in the place of mountain ash occurrence also 5-10 year old spruce and fir trees were found. These tree species lastingly resettle areas where the ground is stabilised, which needs more time than mountain ash succession. As the result of the episode in ca. 1905, one landslide scarp developed below the tourist trail "Górny Płaj". This trail was traced in 1883 and until 1939 was the main trail leading to the tourist shelter opened for tourist in 1906 at the northern slope of Mt. Babia Góra (Fig. 2a). Above the scarp, up the altitude of tourist trail (1180 m a.s.l.) or even higher, other scarps developed in colluvial cover which destabilised the tourist trail

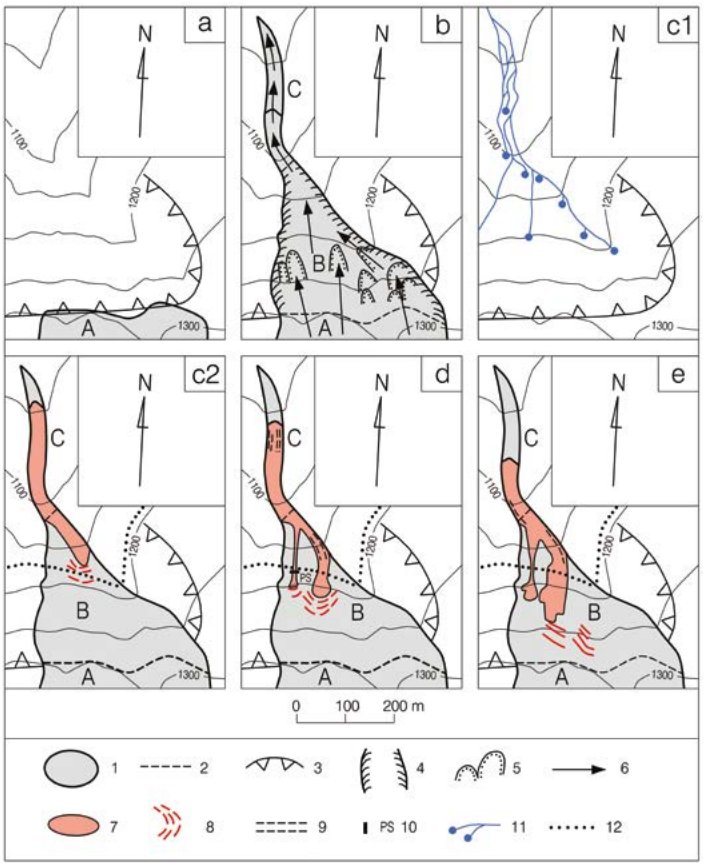

Figure 9. Reconstruction of the Cylowa Zerwa landslide – debris flow development since 1868. Limit of the object: a – before 1868 (the lowest located part of segment A is marked); b – directly after 1868 (segments: A, B, C); limit of the area where changes in landslide – debris flow relief occurred: c – after 1905, d – after 1962, e – during the period 2000-2004. Part "c" shows: c1 – present-day occurrence of springs and streams in the bottom of the Klinowy Stream headwater area, c2 – limits of changes in landslide – debris flow area after 1905. 1 – the Cylowa Zerwa limit (without the major part of the segment A); 2 – boundary between segments A and B, and B and C; 3 – limit of the eastern part of the Klinowy Stream headwater; 4 – tongue built of debris which originated in 1868 in the segment B; 5 – lobes originated in 1868 in the segment B; 6 – direction of material movement in 1868, 7 – areas where changes in relief of the Cylowa Zerwa landslide – debris flow occurred after 1905 (scarp and landslide channel in segment B, majority part of segment C); 8 – new scarps above the larger (main) scarp; 9 – levee; 10 – Płaczliwa Skała (Crying Rock); 11 – springs and streams; 12 – tourist trail "Górny Płaj"

after 1905. In the 1910s and 1920s many Swiss stone-pine trees (*Pinus cembra*) were planted along the trail in order to stabilise the ground and minimalize the damage (Archive of the Babia Góra NP).

The cause of activation of the Cylowa Zerwa landslide in the lower part of the segment (B) at the beginning of the 20th century was probably a headward erosion in the area, where many springs occurred in the lowest located part of the headwater area of the Klinowy Stream (Fig. 9c1). This process was favoured by large slope gradient of this part of the slope (Fig. 5). The slipped mass of colluvial material was deposited in the segment (C), probably not along its whole length.

The landforms which originated at that time underwent later changes.

The third stage of the Cylowa Zerwa landslide activation occurred at the beginning of June 1962, because of abundant rainfalls. The dislocation of debris material rather in form of a debris flow than a sliding occurred above over 50 year older scarp. This caused total damage of tourist trail and development of a new scarp, the edge of which reached the altitude 1210 m a.s.l. The scarp was up to 30 m wide, and the landslide channel was up to 20 m wide. This stage of landslide activation was documented in photographs (Fig. 10). In the succeeding years some fading mass movements occurred below the scarp, and were most intensified in 1968. The Cylowa Zerwa landslide became stabilised after 1970 and since then for over 30 years the tourist trail was not remediated (Archive of the Babia Góra NP). After 1962 the second smaller scarp developed at 1200 m a.s.l. on the western side, and below it a narrow landslide channel appeared which joins the larger landslide channel. Since then, in the bottom of the smaller landslide channel (above the tourist trail) a landform called Płaczliwa Skała (Crying Rock) has been visible. Above the main scarps, especially the larger one, fissures and smaller scarps developed which reached the altitude 1230 m a.s.l. The old-growth spruce forest present in this area showed features of a drunken forest (Łajczak, 1998, 2008).

The development of the landslide in the third stage of its activation represented only continuation of the process which had started earlier, which was favoured by large slope gradients of the headwater area. Debris material displaced from the both scarps (especially from the larger one) was deposited in the segment (C), but not along its whole length, which resulted in step-like deepening of the longitudinal profile of the landslide tongue. The levees originated during the debris material transportation at the sides of the larger landslide channel, which separated 7 m deep depression (Fig. 10), represented specific elements of the morphology of this part of the landslide for the next 40 years. Fig. 9d shows the extend of the part of the Cylowa Zerwa landslide which changed after 1962. The landforms within the landslide which developed during that stage were remodelled later.

The last stage of activation of the Cylowa Zerwa landslide occurred in two phases: more extensively in April 2000 during melting of thick water-soaking snow cover, and less extensively in summer 2004 (Archive of the Babia Góra NP). This stage of landslide activation has the richest documentation (LiDAR image of 2014, photographs, results of detailed geomorphological mapping, and repetitive observations). Remodelling of the landslide consisted in retreating up the slope the both scarps (the larger one up to 1230 m a.s.l., and the smaller one up to1215 m a.s.l.), which occurred after dislocation of the debris packages which separate older scarps. The width of these scarps also increased (the larger one up to 65 m) as well as the width of the larger landslide channel increased up to 40-50 m. At present both scarps are separated by a narrow, locally up to 3 m wide belt of the slope, where the displacement of debris material has not occurred yet. Below the scarps the fading mass movements were continuing after 2004 for about 10 years. Since 2015 no renovation works of the tourist trail have been done. After the increase of the scarps limit in the uppermost

Figure 10. Larger landslide channel of the Cylowa Zerwa which originated in June 1962. The photograph shows the state in July 1962. x – tourist trail "Górny Płaj"

Source: Archive of the Babia Góra National Park.

part of this slide, above their edges up the altitude 1275 m a.s.l., up to 5 m deep younger scarps have developed in the colluvial cover. The old-growth spruce forest adjacent these scarps shows features of a drunken forest.

Debris material transported from the larger scarp filled the depression between the levees in the larger landslide track, and slightly overbuilt these landforms, which resulted in the decrease of denivelation in transversal profile of this section of the landslide by 4 m. Also within the landslide tongue, older levees became overbuilt and the new ones were created, but only along the half of its length. In the further course of this segment of the landslide any essential changes in the landslide relief did not occur. After 2004 a torrential cone started to develop below the smaller landslide channel, and its present-day length is 80 m. This landform fills the lower section of the western landslide track and penetrates into the lower located larger (eastern) landslide track (Fig. 4). Fig. 9e shows changes of landslide extend which have occurred after 2004. Since 2015 any essential changes in landslide relief have not occurred.

Summarising, the stage of changes in the extend and relief of the Cylowa Zerwa landslide which occurred in 1868 should be assumed as a preliminary stage for further changes of this object. During this stage debris colluvia covered part of the slope within the headwater area of the Klinowy Stream (segment B of the landslide) and filled the bottom of the upper part of the valley (segment C of the landslide). At this stage, the landslide reached the maximum coverage, and further changes which occurred in 1905, 1962 and 2000-2004 consisted in redistribution of the material deposited earlier in segment (B). Changes in the relief of this part of the Cylowa Zerwa landslide since the beginning of the 20th century consisted in:

1. Upslope extension of the zone of the debris material occurred, at first along one line (1905), and then along two lines (1962 and 2000-2004),
2. Loss of debris material on the slope in upper sections of landslide tracks occurred,
3. Overbuilding of lower sections of landslide tracks and shortening the distance of debris deposition on landslide tongue (segment C of landslide) during the succeeding activation of the landslide,
4. The largest increase in thickness of deposited material in the lower part of the larger landslide track and in the upper part of the segment (C) of the landslide, which is shown by transversal profiles II-V (Fig. 8). This process was the result of alternate overbuilding the levees and filling out the depressions between these landforms with debris material,
5. Development of step-like longitudinal profile of the segment (C) of the landslide (Fig. 5).

The active part of the Cylowa Zerwa – from landslide (slump) to a debris flow?

The way of transportation of debris material in segment (B) during the stage of activation of the Cylowa Zerwa landslide in 1868 and landforms originated in segments (B) and (C) of the landslide during the stages of its activation in 1868, 1905, 1962 and 2000-2004 indicate nevertheless that in that part of the landslide the consequences of debris flow are visible. The studied object does not show however entire similarity to classical debris flow located on the northern slope of Mt. Babia Góra under Diablak culmination which originated in July 2002 (Łajczak & Migoń, 2007). As a result of debris flow under Diablak, four groups of landforms successively developed down the slope: (1) shallow hollow in debris cover which represented the source of the displaced material, (2) new erosional channel in the couloir bottom, which played the role of transit section, (3) a channel cut in torrential cone and the adjacent levee on the both sides, (4) cumulation of debris material in front of spruce trunks in the final section of debris flow.

The following landforms in segments (B) and (C) of the Cylowa Zerwa mass movements may be recognised as the consequences of debris flow:

1. A wide zone of debris cover in the segment (B) of relatively "smooth" morphology formed as a 3 m thick tongue bounded by long scarps, with numerous lobes (Figs. 3, 4, 6). This zone of debris flow penetrated a narrow valley bottom. Relief of this accumulation landform became changed during the succeeding stages of the Cylowa Zerwa activations. In the upper part of the segment (B) or in the lower part of the segment (A) there is no large head scarp, which could have been a source area of the displaced material. Such area is probably represented by rock packages covered by debris colluvia in the segment (A), which were activated due to seismic tremor (a suggestion) and which then caused the flow of debris material during heavy rains pointed by H. Zapałowicz (1880). This source of debris flow supply of 1868 should be recognised as considerably efficient taking into account the volume of the displaced material of about 370,000 m^3 (average thickness of the deposited material together with the landslide tongue is 5 m) on the area of 7.4 ha and the length of 740 m. The denudation rate of segment (A) should be estimated as 3.9 m,
2. Two landslide scarps in the segment (B) relocating up the slope during the succeeding stages of the Cylowa Zerwa activation, were the source of debris material transported along the landslide channels to the segment (C) in the years 1905-2004. The volume of the material derived from these scarps and from the upper sections of landslide channels was estimated to 42,000 m^3 (average thickness of material loss is 3 m),
3. Levees in the lower part of the larger landslide track and within the segment (C) of the landslide as well as zones of depressions separating the levees. The depressions were filled with colluvium. Average thickness of material deposition in the lower part of larger landslide channel and within the segment (C) of the landslide only during the Cylowa Zerwa activation in 1962 and 2000-2004, was estimated to about 3.5 m,
4. acumulation of rock debris in front of tree trunks in the middle and lower parts of the segment (C) of the Cylowa Zerwa mass movements was estimated to several m^3.

The mentioned landforms in the segments (B) and (C) of the Cylowa Zerwa mass movements should be classified as landforms which were transformed several times by debris flows every ca. 45 years since 1868. The group of these landforms is located below the segment (A) of the landslide, which represented a rich source of debris material in the first stage of the Cylowa Zerwa activation, and which underwent fluidization downslope.

The Cylowa Zerwa called recently a landslide, in fact represents two groups of landforms which originated as a result of either sliding or debris flow. It is necessary therefore to redefine this geomorphological object and pointed it out as an example of the landform group of complex origin.

Relationship of dates of the Cylowa Zerwa activation and annual increments of spruce

In the lower part of the segment (B) and within the segment (C) of the Cylowa Zerwa mass movement, eight spruce trees were selected at the altitude range of 1040-1160 m a.s.l. in order to determine their age, years of growth reduction, years of release, and other data (Tab. 1). The selected spruce trees grow along the eastern limit of the study object, and, among them, the trees no. 5-8 grow in the axial zone of the right-side levee (Fig. 11). These spruce trees grow in 4 sections of segment (C) and (B) of the Cylowa Zerwa, and the age of which was preliminarily determined as 1868, 1905, 1962 and 2004. In each section of segments (C) and (B) of the study object, the oldest spruce trees were selected because they should contain records in tree-rings of the longest history of episodes concerning mobility of debris material activation.

The spruce tree no. 1 is located in the oldest part of the Cylowa Zerwa tongue just above its front which originated in 1868. The spruce trees no. 2 and 3 occur above

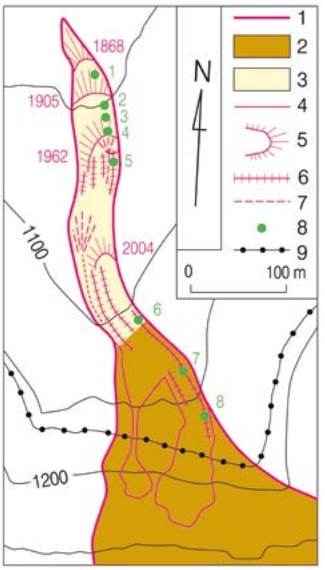

Figure 11. Relief of the lower part of the segment (B) and the segment (C) of the Cylowa Zerwa landslide – debris flow and location of eight Norway spruce trees (*Picea abies* L. H.Karst), which were the sources to obtain increment drillings using Pressler corer. 1 – limit of the lower part of the Cylowa Zerwa landslide – debris flow; 2 – segment (B); 3 – segment (C); 4 – upper limit of the part of the Cylowa Zerwa landslide, where relief became changed due to landslide activations since 1868; 5 – front of the deposited debris material during activation stages (1868, 1905, 1962 and 2000-2004); 6 – levee; 7 – erosional cutting of the segment (C) and the alluvial fan; 8 – location of the examined eight spruce trees; 9 – tourist trail "Górny Płaj"

the landslide tongue front which originated in 1905, and the spruce trees no. 4 and 5 grow within the landslide front which developed in 1962. The spruce trees no. 6-8 grow in the levee section overbuilt in 2004. The analysis of the obtained core samples gave the following information concerning the successive sections of the studied part of the Cylowa Zerwa:

- **Spruce tree no. 1** has grown since ca. 1900 on the landslide – debris flow front which was formed in 1868. The vertical arrangement of the trunk indicates stabilised ground. The roots are not covered by debris material which shows that there was no material deposition in the younger stages of the Cylowa Zerwa activation,
- **Spruce tree no. 2** is a blown down tree which, judging from the trunk diameter, grew for about 150 years. It is not possible to estimate the year when the tree became knocked down. In the visible lower decayed part of the trunk, the roots are totally covered by debris material. This tree originated before 1868. The lower part of its trunk was strewn with debris material in 1868 and probably in 1905,
- **Spruce tree no. 3** has grown since 1840, and similarly to the spruce tree no. 2, its roots are totally covered by debris material. Reductions in tree-rings indicate the ground mobility in 1867/1868, 1946/1947 and 2004/2005. The first date should be related to active stage of the Cylowa Zerwa at the end of May 1868 (before growth season). It is difficult to explain the second and the third dates. In annual increments of the spruce tree no. 3, the episode of 1905 was not marked,
- Decayed trunk of **spruce tree no. 4** located within the landslide – debris flow front which was formed in 1962. Judging from the diameter of the trunk, the tree grew for ca. 150 years, but it is not possible to estimate the year when the tree was knocked down. In the visible lower part of the trunk the roots are totally covered by debris material. This spruce tree probably also appeared before 1868, and the lower part of the trunk was strewn with debris material in 1868, 1905 and possibly also in 1962,
- **Spruce tree no. 5** is the oldest one among the dated trees. It has grown since ca. 1835 on the right-side levee within the front of the landslide – debris flow, which formed in 1962. The roots of spruce are totally covered by debris material. Two increment reductions in this tree were dated. Taking into account the measurement error, the beginning of the first one (1966/1967) may be related to the episode of 1962. It is difficult to explain the beginning of the releasing dated for 1863/1864,

- **Spruce tree no. 6** has grown since ca. 1845 on the right-side levee within the landslide – debris flow front which originated in the activation phase of 2000-2004. In the case of this tree, only the beginning of the only growth reduction in 1979/1980 was determined, which is difficult to relate to stages of the Cylowa Zerwa activation. Two beginnings of releases were determined. The first one dated to ca. 1873/1874 may be related to the episode of 1868. The roots of the spruce are covered by debris material deposited during four stages of the Cylowa Zerwa activation. This is the oldest spruce tree which grows on such high altitude within the studied part of the landslide, which has not been blown down since 1868,
- **Spruce tree no. 7** which has grown since 1984 in the same morphological situation of the landslide – debris flow as the spruce tree no. 6, but it is located 30 m higher. There is no record in the tree increment concerning the episode of 2000-2004,
- **Spruce tree no. 8** has been growing since 1984 at the altitude of 1160 m a.s.l., also on the right-side levee. The beginning of the release dated to 2005/2006 should be related to the last stage of the Cylowa Zerwa activation in 2000-2004.

Basing on the mentioned above information, the determined limit of deposition of debris material in the segment (C) and in the lower part of the segment (B) of the Cylowa Zerwa during the stages of activation in 1868, 1905, 1962 and 2000-2004 may be assumed as legitimate.

Natural, landscape, social-economic and political consequences of the Cylowa Zerwa activations

The Cylowa Zerwa landslide – debris flow is located at the borderland of two forest communities, i.e. fertile Carpathian beech wood of lower montane forest, and acidophilous West Carpathian spruce wood of upper montane forest (Holeksa & Szwagrzyk, 2005). The subsequent stages of the Cylowa Zerwa activation caused the replacement of the forest formation by communities of herbs and grasses with local domination of shrubs (Silesian willow – *Salix silesiaca*). Segment (C), which was supplied with debris material from the upper part of segment (B), at first was taken over by Norway spruce (*Picea abies* L. H.Karst) trees. This species is not able to occupy bare surfaces in the segment (B), where only locally its numerous individuals occur after the last stage of the Cylowa Zerwa activation, i.e.

Table 1. Characteristics of cross-dated samples

No. of a tree	First tree-ring [year]	Year (c.a.) of tree origin	Growth reductions - initial year	Growth releases - initial year	Other information
1	1923	1900	-	-	-
2	-	-	-	-	-
3	1863	1840	1867/1868 1946/1947 2004/2005	1886/1887	numerous traumatic resin ducts 2005-2021
4	-	-	-	-	-
5	1857	1835	1966/1967 1978/1979	1863/1864 2000/2001	-
6	1855	1845	1979/1980	1873/1874 1988/1989	-
7	1994	1984	-	-	-
8	1990	1980	-	2005/2006	-

The age of trees no. 2 and 4 was not determined (the inner part of trunks were decayed)

in 2000-2004. Older blown down spruce specimens were dislocated with debris material to lower located parts of the Cylowa Zerwa object, where deposited mineral material contains large accumulation of dead timber (Łajczak, 2008).

The extend of herb and grass vegetation together with Silesian willow was shifted up the slope above the tourist trail "Górny Płaj" after 1962, and more extensively after 2000-2004. This made it possible not only to observe a large part of the Cylowa Zerwa area, but also to improve view values of this part of Mt. Babia Góra.

Activation of the Cylowa Zerwa since 1905 has caused periodical damage of tourist trail "Górny Płaj" which had been designated in 1883. The repair works of this trail after 1962 and 2004 lasted for several years. During that time the trail was periodically closed up which caused impediments to tourist traffic (Archive of the Babia Góra NP). It should be mentioned that during the sudden activation of the Cylowa Zerwa at the beginning of June 1962, in the conditions of long-lasting, intensive rainfalls (Fig. 10), a group of several dozen children that were walking along this trail, luckily avoided the disaster.

After the stage of the Cylowa Zerwa activation in 1905, fissures and scarps developing above the main scarp (Fig. 9c) endangered slope stability along the tourist trail "Górny Płaj". Planting many Swiss stone-pine (*Pinus cembra*) trees in this area in the 1910s-1920s aimed to keep the trail in trim, which, after opening the shelter of the Tatra's Society in 1906 on the northern slope of Mt. Babia Góra was the most popular route to reach the shelter. Thread to the tourist trail in the Cylowa Zerwa area was not at that time touted in order to have high tourist movement in the Polish shelter, which competed with German shelter of Beskidenverein organisation from Bielsko, which was built in 1905 at the southern slope of Mt. Babia Góra summit (Fig. 2a). This is probably the only plot of political nature connected with the landslide functioning in the Carpathians.

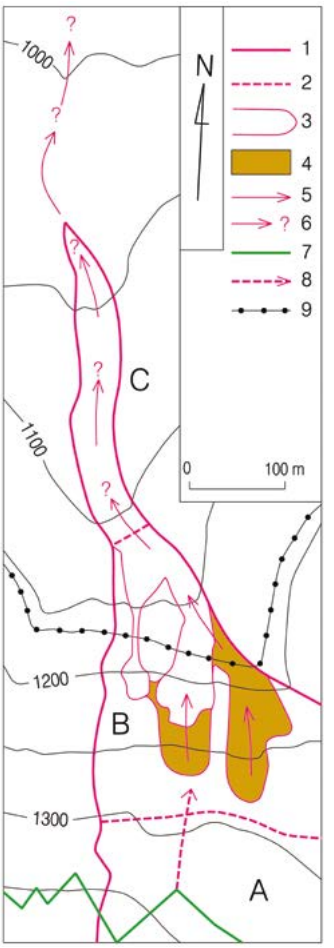

Figure 12. Probable changes in relief of the Cylowa Zerwa landslide – debris flow during the future phase of its activation. 1 – contemporary limit of the Cylowa Zerwa; 2 – boundary between segments (A) and (B), and (B) and (C); 3 – present-day upper limit of the Cylowa Zerwa part, where relief changed due to landslide – debris flow activation in the period 1868-2004; 4 – probable extend of the areas from which the debris material will be removed earliest (Fig. 6); 5 – supposed route of material transportation, place of its deposition depends on the amount of the activated material; 6 – different variants of the length of the transported material (transportation below the contemporary tongue front possible in further stages of the Cylowa Zerwa activation); 7 – timberline; 8 – probable avalanche route in further future, which may reach the highest located scarp in the segment (B); 9 – tourist trail "Górny Płaj"

Prognosis of further development of the Cylowa Zerwa landslide – debris flow

Reliable prognosis of the further development of the Cylowa Zerwa landslide – debris flow may concern only the next, fifth stage of this object activation. This episode, considering the time span of ca. 45 years between the hitherto activity stages, will probably occur in 2045. The areas in the segment (B) of the landslide – debris flow which are the most vulnerable to debris material displacement include: (a) a zone with scarps above the larger scarp, where drunken forest dominates; (b) a narrow zone of the slope between two scarps; (c) vaster area at the eastern side of the larger scarp, where, up to the altitude of 1275 m a.s.l., numerous scarps occupied by drunken forest occur as well as colluvial tongues. The last mentioned area includes also lower located part of the slope up to the altitude of about 1150 m a.s.l. (Fig. 12). The contemporary hypsometry and topographic features of the areas (a), (b) and (c) are shown in Figs. 3, 4, 6, 9e. Displacement of debris material from area (a) and especially area (c) will cause destruction of tourist trail "Górny Płaj" along the section of about 100 m. Deposition of this material will probably take place in the upper part of segment (C) of the Cylowa Zerwa, but it may include further part of this segment if relatively larger mass of material will get active.

Further retreat of landslide – debris flow scarps up the slope in the segment (B) of the Cylowa Zerwa as far as the boundary with the segment (A), and also their joining and widening may occur in the next stages of the study object activation, however it is not possible to predict its date. In further future it may be possible that the lowest located snow avalanche routes under the Brona Pass will join the highest located young scarps within the Cylowa Zerwa landslide – debris flow. Produced in such conditions long avalanche-landslide-debris flow routes will efficiently resist the succession of dwarf mountain pine bushes and spruce forest. They may also become an efficient source of debris material supplied even to the bottom of the Klinowy Stream Valley below the range of the segment (C) of the Cylowa Zerwa object. Such a distant extend of avalanches is pointed by a situation in the adjacent the Cylowy Stream Valley (Łajczak & Spyt 2018) the development history of which is similar to the Klinowy Stream Valley.

The progressive overbuilding of the segment (C) of the Cylowa Zerwa landslide – debris flow with debris material may cause, in further prospect, imbalance of colluvia and their movement down the valley which will cause the shortening of the section of the Klinowy Stream Valley with no colluvial cover.

Conclusions

The Cylowa Zerwa landslide – debris flow is the only one among the studied landslides of Mt. Babia Góra which is distinguished by clear bipartite nature of its relief. The upper part of this geomorphological object includes step-like arranged and backwardly rotated rock packages on the slope, whereas the landforms of the lower and middle parts of this object resemble landforms originated in conditions of a debris slide according to Dikau et al. (1996) or even debris flow. Such origin of this part of the Cylowa Zerwa landslide or/and debris flow is indicated by the description of debris material movement in May 1868 (Zapałowicz, 1880), and also by landforms which originated during the succeeding stages of the geomorphological object activation. Another distinguishing feature of the Cylowa Zerwa landslide – debris flow is a cyclical process of its activation which has occurred over the last 150 years every ca. 45 years and which has included exclusively its middle and lower parts.

The Cylowa Zerwa landslide – debris flow occurs within over 400 m wide altitude interval (1430-1024 m a.s.l.), it contacts with structural flattenings of plateau, where it is adjacent to Main European Watershed and to Polish-Slovak boundary, and simultaneously penetrates to a deep valley of the Klinowy Stream. Two tourist trails go across the landslide – debris flow, and one goes along

its upper limit, which makes this object accessible for observations, especially the part which undergoes periodical reviving. Easy access to the vast part of the Cylowa Zerwa landslide – debris flow causes that this geomorphological object possesses high education values. Also the value of the Cylowa Zerwa landslide – debris flow as a geotourist object is very important, therefore it should be more extensively included in education activity of the Babia Góra National Park.

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