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DEVELOPMENT OF TOURIST INFRASTRUCTURE ON BABIA GÓRA MT. (WESTERN CARPATHIANS) IN CONDITIONS WHERE THERE IS RISK DUE TO SLOPE PROCESSES

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Abstract: The aim of the paper is to evaluate the sustainability of the location of all elements of tourist infrastructure on the slopes of Babia Góra Mt. in the Western Beskidy Mountains taking into account local relief and a range of geomorphologic processes. For more than 130 years, local tourist facilities remained unthreatened by slope processes with the exception of very limited sections of the northern slope. A deep-seated landslide reactivated in the mid 19th century affected a small section of that slope that is outside of regular tourist traffic while another landslide, a shallow one that remains active, has been damaging a single marked tourist trail. Debris flows observed locally on the northern slope are not typical of contemporary relief dynamics across Babia Góra Mt. and therefore cannot be regarded as a universal threat to local tourist infrastructure. In addition, snow avalanches that reach short stretches of tourist trails on the northern slope have not damaged them. The current hazard status of the tourist infrastructure on Babia Góra Mt. is clearly better than it would have been if certain heavy development plans had been carried out in geomorphologically vulnerable areas.

Keywords: flysch, landslides, debris flows, avalanches, tourist infrastructure, Babia Góra Mt., Western Carpathian Mountains

Introduction

The development of tourism in the Polish Carpathians from 1850 to the present has been accompanied by the construction of tourism facilities usually located on the slopes of mountain ranges with significant landscape value. Facilities for the use of tourists such as mountain huts, shelters, waymarked trails, cable cars, and chair-lifts have been built, and ski runs with ski lifts have been prepared for skiing. Rational planning of tourist infrastructure should take into account the range of geomorphological processes which may occur, which may model mountain slopes and which may present a danger to the facilities. Information on the processes modelling the slopes in the Polish Carpathians and representing a potential danger to tourist infrastructure is included in numerous papers (e.g. Kotarba 1992, 1997; Kotarba, Pech 2002; Gorczyca 2004; Łajczak, Migoń 2007; Rączkowska *et al.* 2012; Łajczak *et al.* 2014a). In this part of the Carpathians composed of flysch, landslide movements are among those processes which show the largest territorial range in the whole altitudinal profile (Bober 1984; Margielewski 2004, 2006; Rączkowski 2007; Margielewski *et al.* 2008; Łajczak *et al.* 2014a) and their results may be observed on tourist trails. The trails themselves, however, suffered only sporadically and in spatially limited areas. This has been changing over the last 20 years, as the reactivation of landslides in the flysch Carpathian Mountains of Poland, the Czech Republic and Slovakia (Klimeš *et al.* 2009; Klimeš, Blahůt 2012; Gorczyca *et al.* 2013; Pánek *et al.* 2013; Starkel *et al.* 2013) intensified and sometimes covered large areas and so the risk of damage to tourist facilities may be increasing. Other processes, which may be hazardous for the stability of some tourist facilities located on slopes include debris flows and avalanches, however their occurrence in the Polish Carpathians is limited to the Tatra Mountains and the northern slope of Babia Góra Mt. (Hudziak 1987; Kotarba 1992, 1997; Kotarba, Pech 2002; Łajczak 2004; Rączkowska 2006; Łajczak, Migoń 2007; Matyja 2007; Rączkowska *et al.* 2012; Kotarba *et al.* 2013; Łajczak *et al.* 2014a).

This paper includes an analysis of the distribution of tourist facilities on Babia Góra Mt. (1,725 m a.s.l.) the highest ridge in the flysch Western Carpathians (Fig. 1), and background information on the relief of this area and the processes modelling the slopes. Special attention was paid to landslides as they have the most significant influence on the relief of Babia Góra Mt. (Rehman 1895; Niemirowski 1963, 1983; Alexandrowicz 1978, 2004; Ziętara 2004; Łajczak 2014; Łajczak *et al.* 2014b), and especially those landslides which have become active during the last 150 years during which tourist penetration has increased. Debris flow activity since 1997 has been included in the investigations as well as the limits of avalanches observed since the 1970s (Hudziak 1987; Łajczak 2004, 2014; Łajczak, Migoń 2007; Łajczak *et al.* 2014b). Information on the relief of Babia Góra Mt. and its contemporary development, especially the distribution of landslide forms, debris flows and the extent of avalanches, enables an evaluation to be made of the appropriateness of currently completed tourist developments and those which are planned. This is also useful in taking a critical look at certain opinions voiced in scientific publi-

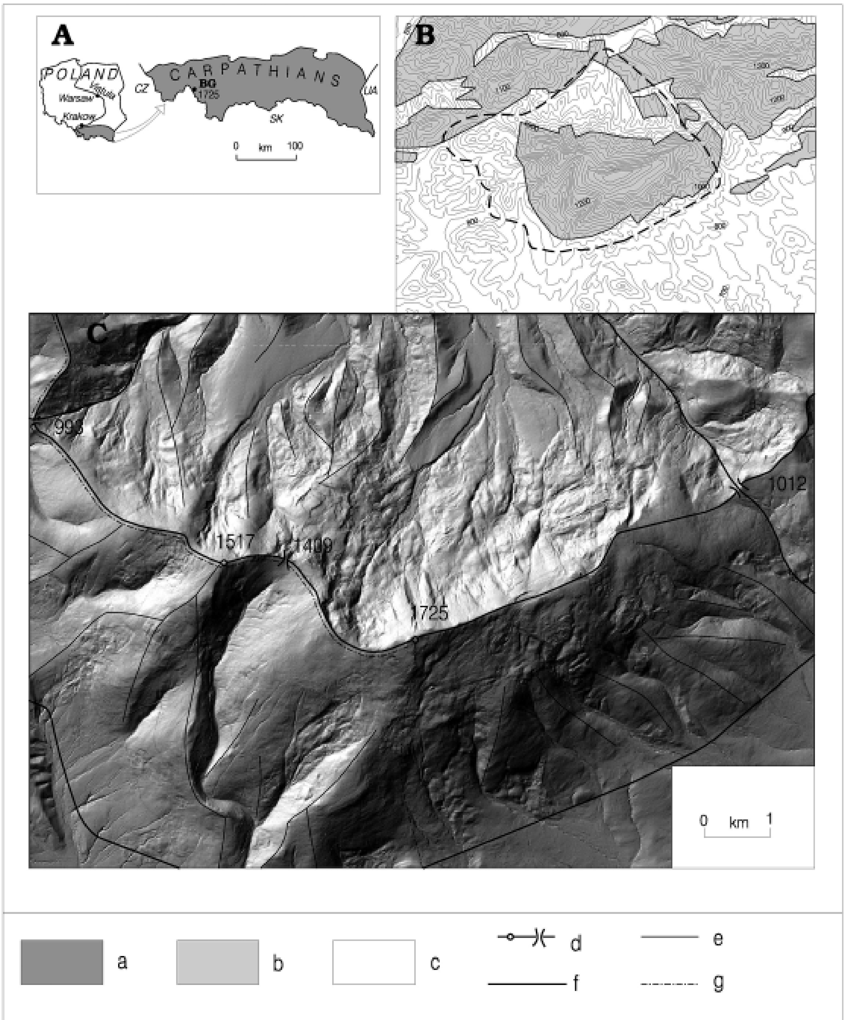

Fig. 1. Study area

Explanations: A – location of Babia Góra Mountain (BG) in Poland, B – limit of Magura sandstone (light grey background) and outcrops of sub-Magura layers (white background) on Babia Góra Mt. and its surroundings, C – pattern of mountain ridges, a – limit of the Carpathians in Poland, b – Magura sandstone, c – sub-Magura layers, d – main ridge with summits and passes, e – lateral ridges, f – boundary of Babia Góra Mt. area, g – Polish-Slovak border, CZ – Czech Republic, SK – Slovakia, UA – Ukraine

Source: authors' own study.

cations (e.g. Ziętara 2004), as well as in tourist outlets and the mainstream media, that the current tourist infrastructure on Babia Góra Mt. is under considerable threat from landslides.

The thematic range of this paper, in line with the concepts set out in publications (Cooke, Doornkamp 1990; Griffiths, Whitworth 2012), allows it to be classified as applied geomorphology. The analysis of potential hazards presented to tourist facilities by slope processes requires an explanation of some concepts: hazard presented by slope processes (H) and risk of occurrence of these hazards (R) (see: Thywissen 2006). The relationship between these concepts can be described by the following relationship: $R = H \cdot V$, where: V – vulnerability to losses. The analysis of the intensity of activity of contemporary slope processes on the slopes of Babia Góra Mt. examined in this paper makes it possible to evaluate a real threat to tourist infrastructure.

The area of investigation

Natural conditions

Babia Góra Mountain (1,725 m a.s.l.) is a homoclinal asymmetric ridge 10 km long, oriented W-E and reaching a relative altitude of 1,100 m (Fig. 1). The main ridge is joined by low lateral ridges. It is the highest mountain in the flysch Western Carpathians. The upper part of the ridge (above 1,000 m a.s.l.) is built of layers of Magura sandstone dipping to the south, whereas the lower part consists of folded and less resistant sub-Magura layers (Książkiewicz 1983; Alexandrowicz 2004). The gradient of the slopes of Babia Góra Mt. varies widely with the steepest sections found on the northern side of the summit cuesta reaching 40° and locally up to 70° (Fig. 1C).

The large energy of the relief of Babia Góra Mountain and the substratum of relatively poor resistance influence the development of deep-seated landslides as a result of the gravitational tectonics of the massif, which includes the upper part of the study area consisting of thick-bedded Magura sandstone (Fig. 2). Such landslides are Holocene forms with Pleistocene foundations (Łajczak 2014). The diverse landslide relief observed across much of the Babia Góra Mt. ridge was formed during the last glacial period, possibly during the thawing of permafrost, and its final formation phase occurred during the Atlantic period of the Holocene (Książkiewicz 1983; Alexandrowicz 2004). There is no available evidence of the movement of deep-seated landslides during the last 400 years, i.e. since the opening of the clearings used for herding purposes which were then taken over for tourism purposes. The only exception is the re-activation of landslide of this type in the mid-19th century on a small section of the northern slope (Łajczak *et al.* 2014b), but

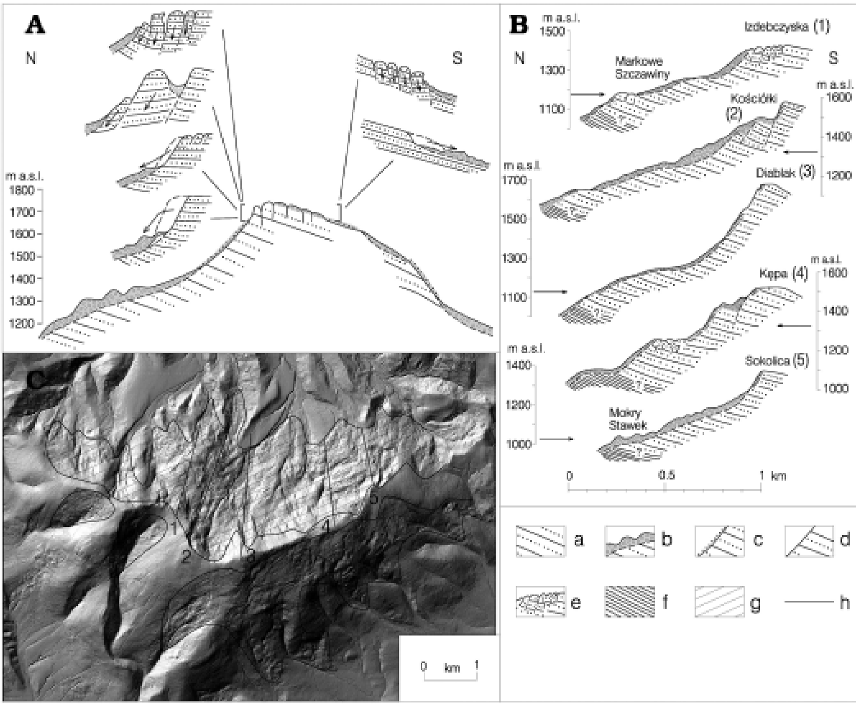

Fig. 2. Deep-seated landslides on Babia Góra Mountain developing in the substratum of Magura sandstone

Explanations: A – typical landslide forms in the highest part of the mountain, B – profiles of the northern slope along places where the largest landslide forms occur (for their location see part C), C – limit of deep-seated landslides together with the thickest layer of colluvium, a – Magura sandstone, b – thick layer of colluvium, c – thin layer of slope-wash deposits, d – rock walls without waste-mantle, e – deep fissuring in the bedrock, f – sub-Magura layers, g – limit of the landslides studied, h – location of slope profiles (1–5)

Source: authors' own study.

outside of areas explored by tourists. Development of these landslides is controlled by the distribution of fissures predominantly running NW-SE and SW-NE (Łajczak 2014). The most frequently occurring landforms within the area of deep-seated landslides include ridge and slope trenches with crevice -type caves, escarpments, rock walls and headwalls. Below these forms, the slopes are covered with a thick, layer of debris and block colluviums (slope wash deposit) locally reaching 30 m deep (Fig. 2C). Ramparts and hummocks occur in such places, as well as tongues and wide lobes which go down to valley headwater areas. These forms are accompanied by landslide shelves and depressions filled with bog-springs, peatbogs and miniature lakes. Landslide headwalls at the cuesta are deeper and occupy smaller areas than those which developed on the slope convergent with the dip of Magura sandstone layers. They are accompanied by thicker mantles of slope wash deposits. The slopes of Babia Góra Mt. covered by deep-seated landslides together with thick mantles of colluvium deposits occupy 80% of the ridge area within that part built of Magura sandstones. The remaining 20% of the slopes on this part of the ridge are covered by thin mantles of colluvium deposits and their profile is smoother. This area features debris flows and actually only one shallow debris landslide was reactivated in the mid-19th century (Łajczak 1998), which, however, poses a real threat to tourists.

The northern slope of Babia Góra Mt. receives precipitation ranging from 1,000 mm at the slope-foots to 1,500 mm at an altitude of 1,200 m a.s.l. and over 1,200 mm on the summit area. Half of the total precipitation occurs in the summer months. Very intense total daily precipitation occurs in summer and this often lasts several days and exceeds 100 mm, sometimes even reaching 300 mm (Obrębska-Starkel 2004). Large volumes of water are stored in a thick snow cover which melts most rapidly from March to May and up until early summer (Łajczak 2004).

Highly permeable skeletal soils covering the whole Babia Góra Mt. ridge (Miechówka *et al.* 2004) as well as dense forest stand showing features of ancient woodland (Parusel *et al.* 2004) and extensive mountain dwarf pine favour rapid infiltration of rain water and meltwater. Relatively deep circulation of water is conditioned by landslide morphology, especially on slopes occupied by deep-seated landslides (Łajczak 2012). On slopes covered by a thin layer of colluvium and on slopes without landslides, on the other hand, subsurface flows developing during intense precipitation and thaw episodes only involve the layer of waste-mantle.

Tourist infrastructure

The summit of Babia Góra Mt. is an attractive viewpoint and has been a destination sought by Polish, Austrian, Hungarian, German, Slovakian and Czech tourists. Until the end of the 19th century tourists only used shepherd's paths leading across broad glades which originated on the slopes of the ridge during the period from the 17th to the 18th centuries. The first tourist shelters (which only operated for a few years) were built on the summit in 1807 (a wooden building) and in 1852 (a stone building) (Archive 1). Steadily increasing tourist activity required the preparation of trails on the ground. The first trails were established by the German organisation Beskidenverein at the turn of the 19th and 20th centuries, and then many more were set up by the Polish Tatra Society from the first decade of the 20th century. At present the tourist trails are maintained by the Polish Tourist and Touring Society. Their total length, together with the Slovak side of the massif, is 80 km. The first stone-built mountain hut was built by the Beskidenverein organisation in 1905 on the southern slope of the ridge at a height of 1,616 m a.s.l. It operated until the Second World War. In 1906 a Polish hut was built on the northern side of the mountain at a height of 1,180 m a.s.l. The original wooden building was extended several times up until the 1960s and in 2007–2010 it was replaced by a large mountain hut built of masonry (Fig. 3).

While planning the location of mountain huts and tourist trails, the distribution of shepherd's paths and glades was taken into account as they make use of the more easily accessible parts of the slopes (precipitous slopes and rock walls were omitted). Also tourist attractiveness in terms of scenic views was taken into consideration (Archive 1). However, the risk arising from slope processes was not considered. Locally, these processes started to manifest themselves in the neighbourhood of tourist facilities or became a destructive factor in relation to these facilities. As successive tourist trails have been developed, the locations of the most popular tourist trails leading to the mountain summit have changed several times since the 1890s (Fig. 3). The most significant change occurred in 1968 when a Carpathian road was built which runs from Zawoja across the Lipnicka Pass and Krowiarki glade to Jabłonka. At present the main entrance route to Babia Góra Mt. summit and to the mountain hut runs from the carpark at Krowiarki glade. Simultaneously, the trail running to the mountain hut from the west has become less popular as it is the most vulnerable to slope processes and has suffered local damage from landslide and avalanches (Archive 2).

During the last 5 decades many other tourist facilities have been planned, and were even supposed to be located on the steep slopes of the ridge modelled by debris flows and avalanches, as well as in places with extremely difficult access that were influenced by deep-seated landslides (Archive 1, Archive 2) (Fig. 3). These proposed facilities include: (1) a large mountain hut at Kolista Polana glade with an access road below the existing building; (2) a two-stage cable car to the mountain hut and up to the summit; (3) a chair-lift to the mountain hut continuing above a large landslides to the ridge near Kościółki; (4) cable car to the mountain summit along Polish-Slovakian border on the southern slope; (5) a mountain hut on the summit of the mountain; (6) reconstruction of the mountain hut under the summit of the ridge; (7) chair-lifts and ski trails on the northern slope of Cyl peak; (8) large sacral objects on the summit of the ridge at Diablak. As part of the preparations for investment (1) a popular access trail (known as Górny Płaj) which runs from the carpark at Krowiarki glade to the mountain hut was widened as it was supposed to serve as a road to transport building materials. Apart from this single task, none of the planned investments have been carried out. Plans for the construction of railways in the beginning of the 20th century should also be mentioned. One was supposed to reach Zawoja and the other was supposed to run from Jeleśnia, through

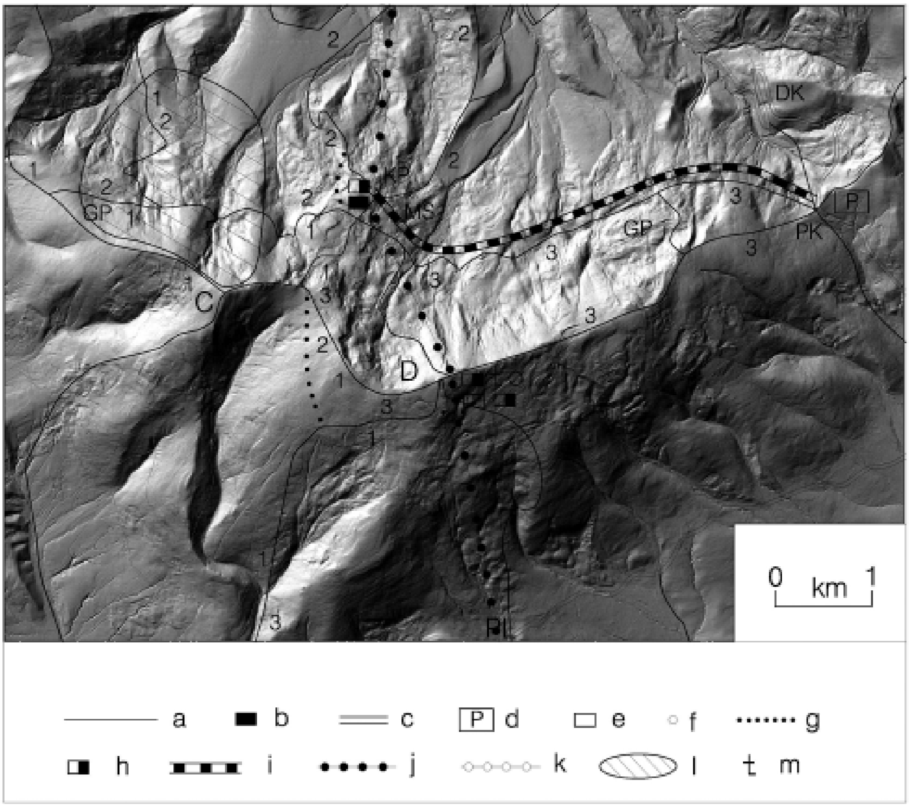

Fig. 3. Distribution of currently functioning, former, and planned in the past tourist facilities on Babia Góra Mountain

Explanations: Functioning facilities: a – tourist trails, b – tourist hut, c – roads, d – car parking. Former facilities: e – tourist hut, f – tourist shelters, g – tourist trails. Facilities planned in the past: h – tourist huts, i – approach road to the tourist hut at Kolista Polana glade, j – cable cars, k – chair-lifts, l – ski trails, m – sacred sites. Tourist trails with the largest tourist traffic: 1 – until 1918, 2 – until 1968, 3 – at present. C – Cyl, D – Diablak, DK – Carpathian Road, GP – Górny Płaj tourist trail, KP – Kolista Polana glade, MS – Markowe Szczawiny glade, PK – Krowiarki glade

Source: authors' own study.

Orawska Polhora, Trstená and Jabłonka to Czarny Dunajec. It was believed that their construction might have launched many tourist investments on Babia Góra Mt. It should also be mentioned that Mosorny Groń, the popular ski resort of Górna Zawoja, is located beyond the area of the Babia Góra Mountain.

State of investigations and aim of the work

Geomorphologists and geologists began focusing on slope processes on Babia Góra Mt. when the construction of tourist infrastructure was already advanced. The state of these investigations should be considered as inadequate to the scale of potential hazards, especially in the case of tourist trails. Attention was paid to the slow creep of debris mantles and blocks on the slopes (Niemirowski 1964; Łajczak 1998; Ziętara 2004) and to the hazard arising from avalanches (Hudziak 1987; Łajczak 1998; Archive 1; Archive 2). The most attention was paid to the damage which has repeatedly occurred to part of the western section of the Górny Płaj tourist trail since 1962. This took place at the point where the Cylowa Zerwa landslide occurred and included the headwater area of the Klinowy Potok stream (Niemirowski 1963, 1964, 1983; Galarowski 1987; Łajczak 1998; Ziętara 2004; Jany 2006). However, forecasts have not been prepared to assess the further development of this landslide, which has resulted in only temporary repairs being carried out to the damaged section of the tourist trail (Archive 1; Archive 2). Small incidents of damage to other tourist trails should be mentioned which have occurred as a result of local slow creep of slope wash material. The very intense erosion of tourist trails should be underlined (Galarowski 1987; Łajczak 1998; Kachel 2008; Buchwał 2010; Archive 2).

The only assessment carried out of the stability of the northern slope of the ridge, which is modelled by deep-seated landslides, concerned the place where the construction of a new mountain hut was planned in the 1960s and the place where a new mountain hut was built in 2007–2010 to replace a pre-existing one. In the first case the evaluation gave a negative result (the mountain hut was not built) and in the second the result was positive (Midowicz 1985; Archive 1; Archive 2). Geomorphological investigations of a debris flow which originated in July 2002 on the northern slope of the ridge (Łajczak, Migoń 2007) did not reveal any hazards threatening the nearby Akademicka Perć (Academics Path) tourist trail at that time. East of this debris flow on the northern slope of the ridge, fossil debris flows with lateral ramparts had developed on torrential cones. They are covered with over 200-year-old spruce trees which provide evidence of the stability of the ground (Matyja 2007).

The objectives of the paper are:
- to evaluate the stability of the slopes of Babia Góra Mountain using LiDAR data and field observations;
- to evaluate hazards to tourist facilities;
- to evaluate the safety of tourist facilities taking into account slope process hazards;
- to evaluate the vulnerability of tourist infrastructure to damage; and
- to evaluate the risk to tourist infrastructure.

This was to evaluate the viability of planned and completed tourist investments. The study searched for the answer to the following question: Which slope processes represent a real hazard to tourist facilities: (1) deep-seated landslides which are re-activated irrespective of hydro-meteorological conditions; (2) the creep of a thin layer of debris waste-mantle along steep slopes in the form of shallow waste-mantle landslides or debris flows; (3) avalanches?

Methods

Information found in the literature on the relief of Babia Góra Mountain was analysed, as well as information concerning the limits and intensity of processes modelling the slopes of the ridge, especially large scale processes. The main information source was a geomorphological map of the area studied prepared at a scale of 1: 5000 (Łajczak 1998). At present, the basic information source concerning the relief of Babia Góra Mt. is comprised of data obtained by Airborne Laser Scanning (Łajczak *et al.* 2014b). Moreover, information was collected on the development and distribution of tourist infrastructure both planned and completed, both past and at present. This information comes from tourist maps, archival materials of the Commission on Mountain Tourism of the Polish Tourist and Touring Society in Babia Góra (Archive 1) and Babiogórski National Park (Archive 2).

Airborne Laser Scanning (LiDAR) commissioned by the Board of Babiogórski National Park was carried out in autumn 2012 with an accuracy of 6 points per m^2. Based on this information source and applying ArcGIS 9.3 software (ESRI), a Digital Terrain Model of pixel resolution 1x1 m was generated. Also a slope reduction map and shaded map of the relief were prepared, all at the same scale. The analysis of this data enabled the authors to describe subtle elements of the relief, especially on landslide slopes, which are difficult to detect in the field due to numerous fallen trees and thick undergrowth. Based on a geomorphological map of the massif (Łajczak 1998) which was developed over the following years, a reinterpretation of the landslide relief of Babia Góra Mt. was carried out and sites were found where landforms hazardous to tourist facilities occur or may reactivate in the future. Fragments of slopes where tourist facilities used to exist in the past and those where they had been planned were also studied. Detailed field observations carried out in summer 2014 enabled the authors to evaluate the current condition of the slopes of the ridge in the vicinity of these sites. This paper shows the graphic results of the LiDAR analysis of 7 fragments of selected sections of the slopes of Babia Góra Mt.

Based on papers by Zapałowicz (1880), Łajczak (1998) and Jany (2006), and information from (Archive 1) and (Archive 2), the development of the Cylowa Zerwa landslide since 1868 was reconstructed and predictions for its further development were presented. This should form the basis for future activities designed to secure the Górny Płaj tourist trail which runs across this area.

In summary, answers to the questions included in the stated objective have been based on the results of research involving literature review, archival inquiries, geomorphologic mapping and LiDAR data.

The evaluation of slope process risk to areas where tourist infrastructure exists, existed in the past or was planned, covers the period from the time when scientific research started in the 19th century. However, as early as from the 15th century, Babia Góra was economically utilised across all its altitude profile, especially in the 17th century, when shepherding was introduced and exploration for iron ore started. The mobility of slopes before the 19th century may only be indirectly estimated basing on the distribution of shepherd's glades and paths in the vicinity of landslides or the distribution of traces connected with past mining works in ridge and slope trenches and in gully walls. Some papers and pictures of Babia Góra Mt. from the 19th century clearly indicate the place and time of development of landslides and debris flows. Such information is also included in records of forest management which has been carried out since the 1840s. Hazards to tourist facilities and local damage to them in the 20th century, especially after the establishment of Babiogórski National Park in 1955, were studied in detail in published papers and unpublished records.

Results of investigations

Evaluation of the stability of the slopes of Babia Góra based on LiDAR data and field observations

The analysis of the relief of Babia Góra Mt. based on LiDAR data and field observations revealed that only in the headwater area of the Klinowy Potok stream on the northern slope of the ridge, did slope processes cause repeated damage to a tourist trail (Górny Płaj). Debris flows dating from 1997, 2002 and 2014 may present future risks to the Akademicka Perć trail running across the northern slope up to the summit of the ridge if they come closer to the trail itself. Avalanches descending to the headwater area of the Cylowy Potok stream sporadically affect the Górny Płaj tourist trail and may represent a hazard threatening its stability.

In other areas on Babia Góra Mt., tourist facilities are not presently endangered by slope processes. The stability of tourist trails is only locally disturbed by the slow creep of slope wash deposits which is observed in the minor deformation of their slope surfaces and in the typical bending of tree trunks. Such a situation is most frequently observed on trails which traverse the slopes of headwater areas. Commonly held opinions based on the observation of slope relief, where the varied landslide morphology gives the impression of ground instability, are in contradiction with the fact that the ground surface of tourist trails is stable along most of their length.

The relief of Babia Góra Mt., with its varied landslide morphology, can be seen in seven test areas (Fig. 4A). Within these areas there are tourist trails with a large frequentation by tourists as well as one working mountain hut and another former hut. The test areas are: A1 – ridge trenches in the area of the Zimna Dolinka valley, 1,500–1,580 m a.s.l., A2 – ridge trenches in Izdebczyska area, 1,360–1,450 m a.s.l., A3 – a headwall under the mountain summit on the southern slope, 1,560–1,680 m a.s.l., A4 – a headwall and colluvium lobe in the Kościółki area on the northern slope, 1,300–1,600 m a.s.l., A5 – slope trenches in Markowe Szczawiny glade area at the northern slope, 1,100–1,240 m a.s.l., A6 – a landslide headwall and colluvium tongue in the Urwane area on the northern slope, 1,060–1,200 m a.s.l., and A7 – a colluvium lobe under Szeroki Żleb gully on the northern slope, 1,050–1,320 m a.s.l. Analysis of Fig. 4 indicates the location of both the working and closed mountain huts and all those sections of tourist trails which were located outside areas with steep slopes and gentler slopes on mobile ground.

Evaluation of hazards to tourist facilities

Deep-seated landslides

Deep-seated landslides which are the most significant landforms occurring on the slopes of Babia Góra Mountain should be considered, with one exception, as stable landforms since the 17th century. This is evidenced by two facts: (1) the stable location and limits of shepherd's clearings and paths with no traces of newer landslide forms; (2) traces of mining works which are still visible in narrow ridge and slope trenches, in gullies, and within the thick layer of slope wash deposits, none of which have been covered up with debris or deformed by the movement of rock masses. None of the tourist trails have been endangered by deep-seated landslides since the time they were laid out for tourists to follow. The closed stone mountain hut located under the summit of the ridge was built on the colluvium rampart below the landslide headwall (Fig. 4B: A3) and no damage was noted during the whole period of its operation. Also the wooden mountain hut located on the northern slope of the ridge was built in a location where numerous slope trenches occur (Fig. 4B: A5) and during its 100-year operation no damage occurred. This is why a new masonry mountain hut was built in the same location and this location is recognised as stable ground. For longer time periods all the deep-seated landslides on the slopes of Babia Góra Mountain should be considered as potentially stable landforms.

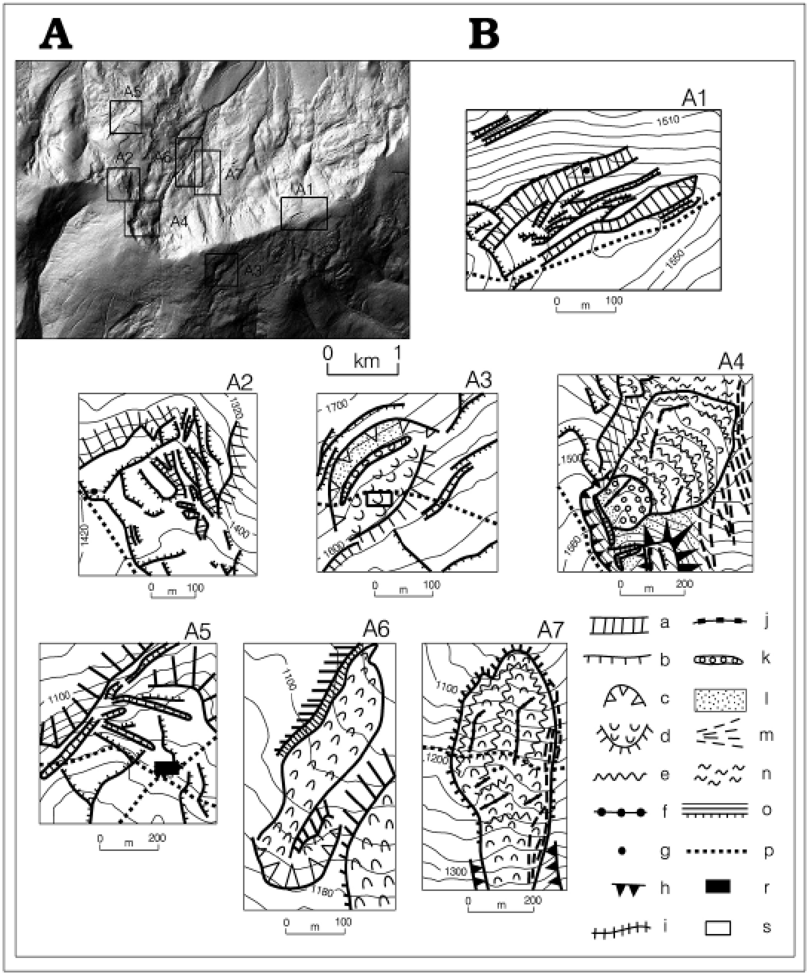

Fig. 4. Landslide morphology of selected areas of Babia Góra Mountain basing on LiDAR data

Explanations: A – location of areas A1–A7, description of the areas in the text, B – geomorphologic sketches of areas studied, landforms: a – ridge and slope trenches, b – landslide escarpments, c – landslide headwalls, d – colluvium tongues, e – axes of bulges on colluvium tongues, f – axes of depressions on colluvium tongues, g – landslide lakes, h – precipitous slopes in places of glacial undercuts, i – convex bends between glacially reshaped headwalls located at different elevations, j – sharp-crested ridge, k – nival ramparts (inactive), l – debris cones, m – torrential cones with fossil debris flows, n – moraines degraded by landslides, o – high terraces with escarpments. Tourist facilities: p – tourist trails, r – tourist hut, s – former tourist hut

Source: authors' own study.

The deep-seated landslide at Urwane and an evaluation of ground stability in the surrounding area

A deep-seated landslide developed in 1868 at a location known as Urwane on the northern slope of the ridge, located about 0.5 km east of the mountain hut at Markowe Szczawiny glade (Fig. 4B: A6). Its colluvium tongue made up of large rocky blocks is covered with forest vegetation. At present this is a still not stable part of the massif, because slope trenches occur above the rocky landslide headwall on its southern and western sides and the trunks of spruce trees are tilted from the vertical which indicates the continuing mobility of the ground. Slope trenches also occur west of this headwall and are visible in the neighbourhood of the mountain hut and also down the slope at Kolista Polana glade where the construction of a large mountain hut and other tourist facilities were planned in the 1960s. Tourist trails also avoid the deep-seated Urwane landslide and are not currently endangered by landslide movements.

The Cylowa Zerwa landslide – an example of an active shallow-seated landslide

A shallow-seated landslide called Cylowa Zerwa started to activate (Fig. 5) in the central part of the headwater area of the Klinowy Potok stream which is located on the northern slope of Babia Góra Mt. and inclined at 35°. This is the only landslide whose development has caused damage to the Górny Płaj tourist trail since 1962. Every 40–50 years, there is repetitive movement of the 2 m thick debris mantle as a result of which the landslide headwall retreats up the hill (Fig. 5B, 5C). After each stage of landslide extension, a slow extinction of landslide movements takes place which lasts for about 10 years which is followed by stabilisation of the whole landslide. Photo 1 shows the state of the landslide after its re-activation in the summer of 1962. The colluviums which build the landslide tongue are deposited in the bottom of the V-shaped valley of the Klinowy Potok stream where their thickness reaches 20 m. The longitudinal profile of the landslide tongue is stair-like and below its steep front the valley shows a V-shaped perpendicular profile. After the original landslide in 1868, it was re-activated in the summers of 1910 and 1962 and in spring 2004. In summer 1968 a side landslide developed which ran parallel to the main one and joined it. Since that time this compound landslide has caused more and more obstruction to the use of the tourist trails which lie at a distance of about 100 m. At present the development of the landslide is connected with the widening of the headwalls which causes the slow displacement of rock packages with spruce forest in the increasing area above the headwalls where slope trenches develop and grow. The upper edge of the larger headwall runs 60 m above the tourist trails at a height 1,230 m a.s.l. (Fig. 5C).

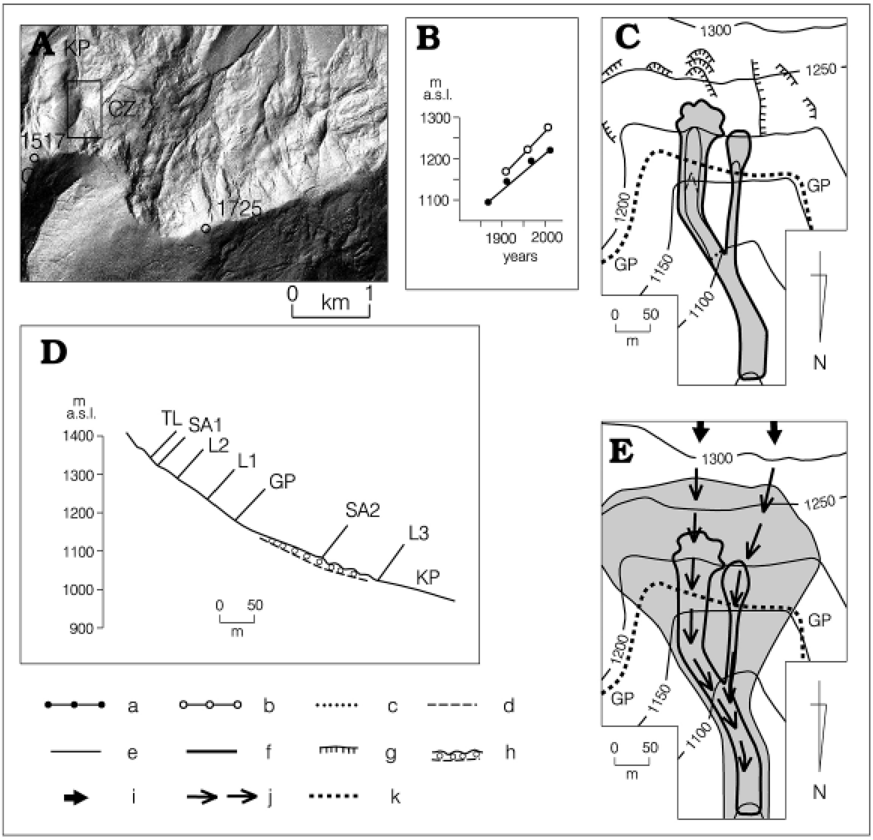

Fig. 5. Cylowa Zerwa landslide

Explanations: A – location (CZ – landslide), B – stages of landslide rejuvenation, C – landslide limit after successive stages of rejuvenation, D – longitudinal profile of the landslide, E – probable growth of the landslide as compared to the present state, possible increase in avalanche paths and increase in destruction along tourist trail; a – upper limit of landslide headwall after successive stages of rejuvenation in 1868, 1910, 1962–1968 and 2004, b – upper limit of escarpments above the landslide headwall after succeeding stages of rejuvenation. Limit of the landslide: after 1868 (c), 1910 (d), 1962–1968 (e), 2004 (f), g – landslide escarpments, h – limit and thickness of colluvium, i – present limit of avalanches, j – probable limit of avalanches in conditions of advanced development of the landslide, k – tourist trail (GP – Górny Płaj). C – Cyl, KP – Klinowy Potok stream. Contemporary situation around the landslide: L1 – upper limit of landslide headwall, L2 – upper limit of landslide escarpments above the landslide headwall, L3 – lower limit of landslide tongue, TL – timberline, SA1 – limit of avalanches. Forecasted situation: SA2 – limits of avalanches in the advanced stage of landslide development

Source: authors' own study.

Photo 1. Cylowa Zerwa landslide after activation in June 1962
GP – Górny Płaj tourist trail
Source: Archive 2.

Further probable development of the landslide will involve the movement of the colluvium material from other fragments of the headwater area to the valley bottom which will lead to the increasing retreat of a larger and larger headwater area up slope. If the edge of the headwall reaches the lowest located fragments of the timberline (which runs above at an altitude of 1,340–1,400 m a.s.l.), the unforested slopes containing the landslide will probably work as a long path for avalanches, which will then be able to descend to a height of 1,070 m a.s.l. on this part of the slope (Fig. 5E). At present the avalanches stop well above the landslide, i.e. at a height of 1,320 m a.s.l. This may cause further difficulties in maintaining the tourist trail as the hazardous section of the trail will increase in length. Periodical closing of the trail, as has happened in the past, will also continue. The increasing thickness of colluvium material deposited below the headwater area in the narrow valley bottom of the Klinowy Potok stream, which is inclined at 20° in this section, may cause activation of a valley landslide which is the continuation of the Cylowa Zerwa landslide. This will not do any damage to tourist facilities as they are located much lower, on the foothills of the northern slope of Babia Góra Mt.

Protection work on the Górny Płaj trail carried out in the 1920's should be mentioned. This was carried out at the contemporary limit of the Cylowa Zerwa landslide. At that time the landslide headwall was located below this trail but was developing up the slope and landslide trenches must have destabilised the trail. To counteract the damage occurring to the trail, numerous stone pines were planted along it so that their roots would stabilise the ground. In 1962 the stone pines and the surrounding spruce wood slid down the slope. This showed that such protection work on the trail will not prove successful because the repeated rejuvenation of the landslide means that vegetation can only stabilise an area for a short period of time.

Debris flows

Debris flows develop on the upper part of the northern slope of Babia Góra Mt. where slope inclinations usually exceed 30° (Fig. 6). Most of the debris flows identified represent fossil forms. Only the lower sections of debris flows with lateral ramparts are visible. They developed on torrential cones located below rock gullies which cut into the steep part of the slope (Fig. 6A). Some debris flows are visible even on the lower parts of the slope where they descend to headwater areas. Two hundred year old spruce trees growing on the lateral ramparts of these debris flows suggest that the ground in this part of the ridge is currently stable. Debris flow, at the moment of its origin, may have included the higher located parts of the slope, i.e. above the segments of these debris flows that are currently visible. They could therefore have included the rock gullies located above and even higher located parts of the slope covered with debris mantle. These sections of debris flows became obliterated as a result of the creeping of debris and block mantles. The well-documented contemporary stability of this part of the northern slope of Babia Góra Mt. makes it possible to suggest an optimistic prognosis for the future operation of the popular Górny Płaj tourist trail. This trail was established in 1883 and traverses the northern slope below most of the fossil debris flows. In places, however, it runs across these forms.

In the years 1997, 2002 and 2004 three debris flows developed on the northern slope near the summit of the ridge (Fig. 6B, No. 1–3). The largest one (No. 2) is 800 m long. They are located near the Akademicka Perć tourist trail. The upper part of the headwall of the longest debris flow is located at an altitude of 1,635 m a.s.l. and its front is located at a height of 1,270 m a.s.l. at a distance of 220 m from the Górny Płaj trail (Fig. 6C). At the time when they commenced activity, these flows did not present a hazard to tourist trails. Only in the case of the longest debris flow did the continuing retreat and widening of its headwall area represent a real threat

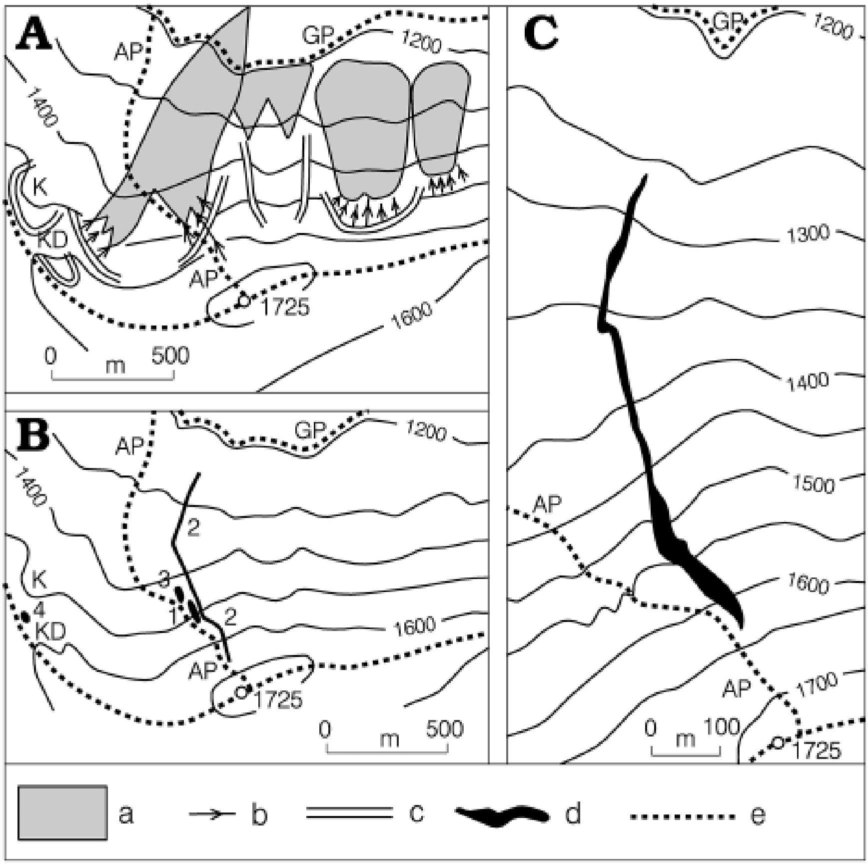

Fig. 6. Distribution of debris flows on the northern slope of Babia Góra Mountain

Explanations: A – limit of fossil debris flows preserved in fragments on torrential cones, B – debris flows developed in the years 1997 (1), 2002 (2), 2014 (3) and debris flow systematically increasing its limit since 2004 (4), C – limit of debris flow from 2002; a – torrential cones, b – gullies, c – glacial undercuttings, d – the youngest debris flows, e – tourist trails (AP – Akademicka Perć, GP – Górny Płaj), K – Kościółki, KD – Kamienna Dolinka valley

Source: authors' own study.

to the stability of the closed section of the Akademicka Perć tourist trail. Thus far the edge of this headwall has approached 10 m closer to the trail and the distance between them is now 20 m. That is why there seems to be a quite real threat to this section of the trail at an altitude of 1,600–1,650 m a.s.l. with the possibility even arising of its destruction and the necessity of laying out a new trail below the summit of the mountain.

In an opposite manner to the linear debris flows discussed above, an irregular debris flow has been continually increasing in size on the upper part of the steep slope of the Kamienna Dolinka valley at Kościółki (Fig. 6B, No. 4). This debris flow, which tourists would find difficult to detect, starts below a sharp morphological edge which is the boundary of the rock-fall and ridge plateau and finishes 20 m below the slope, whereas its width reaches 50 m. This debris flow does not threaten the stability of the tourist trail which runs along the ridge axis on the outcrops of Magura sandstones. Tourists are not allowed access to an area including the slope and the bottom of the Kamienna Dolinka valley.

Avalanches

On the Babia Góra Mountain avalanches occur on the steep northern slope and in some places on the more gentle southern slope. The avalanches usually stop above the timberline or descend slightly beyond this limit (Fig. 7). Three tourist trails which run from the Górny Płaj trail to the mountain summit and to Sokolica and the Brona Pass are closed to tourists during the periods when there is a risk of avalanches. The longest avalanches, up to 1,000 m long, originate in the summit area and go down along the Szeroki Żleb gully crossing the timberline (Photo 2). Occasionally they reach an altitude of 1,200 m a.s.l. descending as far as the Górny Płaj tourist trail. The second area with long avalanche paths is the northern slope of the summit of Cyl (1,517 m a.s.l.) which is the second highest peak of the Babia Góra Mountain. In this location avalanches can reach a length of 800 m and occasionally go beyond the Górny Płaj tourist trail down to an altitude of 1,106 m a.s.l. The existence of such long avalanche paths in this part of the Babia Góra Mt. is the result of former human activity in which large areas of mountain dwarf pine were cleared because of the development of shepherding. This caused increased mobility of the snow cover on the steep slope. The avalanche paths on the slopes of Cyl show their maximum limit which could be reduced were dwarf pine to be allowed to regenerate on the avalanche source area together with spruce along the avalanche paths. The process of regeneration of dwarf pine in this area is, however, little advanced. Short avalanches also develop on small fragments of the southern slope of Babia Góra where they are located on the steep slopes of some landslide headwalls and headwater areas.

An even lower limit of avalanches should be considered possible on the northern slope of Cyl. Large-area forest clearance undertaken between the 1890s and 1920s resulted in the almost total deforestation of the northern slope of Babia Góra Mt. from the foothills up to the Górny Płaj trail. As can be seen in old photographs,

Photo 2. Avalanche below Szeroki Żleb gully at the timberline
Source: Archive 2.

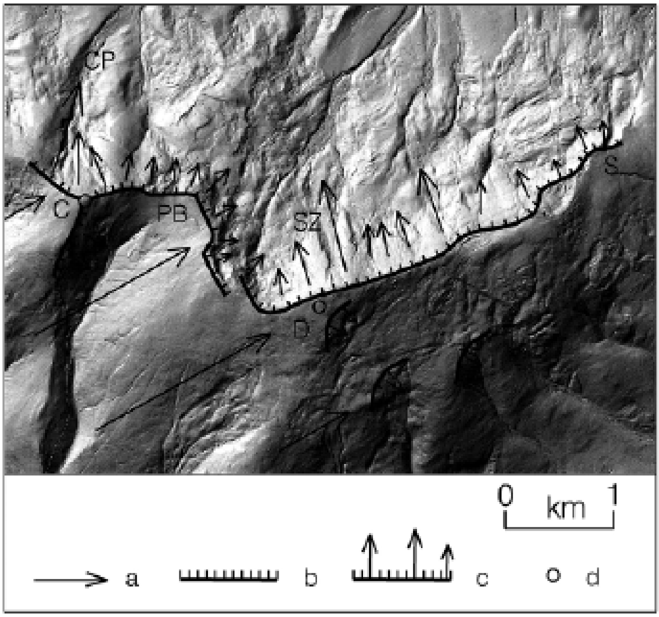

Fig. 7. Paths of avalanches on the slopes of Babia Góra Mountain
Explanations: a – direction of predominant winds in winter and snow blowing, b – snow cornices, c – paths of avalanches, d – summits of Babia Góra (D – Diablak, C – Cyl), CP – Cylowy Potok stream, PB – Brona Pass, S – Sokolica, SZ – Szeroki Żleb gully
Source: authors' own study.

tree-free avalanche paths going down from beneath the summit of Cyl join a totally deforested steep slope below this tourist trail (Photo 3). It is quite possible therefore that at that time avalanches might have descended along Cylowy Potok stream to below an altitude of 1,100 m a.s.l. At the same time there was a real risk in clearing large areas of forest above the Górny Płaj trail on the east side of Szeroki Żleb gully. In fact, forest clearance above this trail had already started at that time. Fortunately, the establishment of a nature reserve on the upper part of Babia Góra Mt. above the Górny Płaj trail (and also on the southern slope on the Polish side) in 1933 protected the mountain and especially its northern slope against slope processes. If the planned large-area forest felling (including a large part of the northern slope above the Górny Płaj trail) had been carried out in the early 1930s, avalanche paths would have become much longer on that part of the slope. This would have caused numerous incidents of damage to some sections of the Górny Płaj trail.

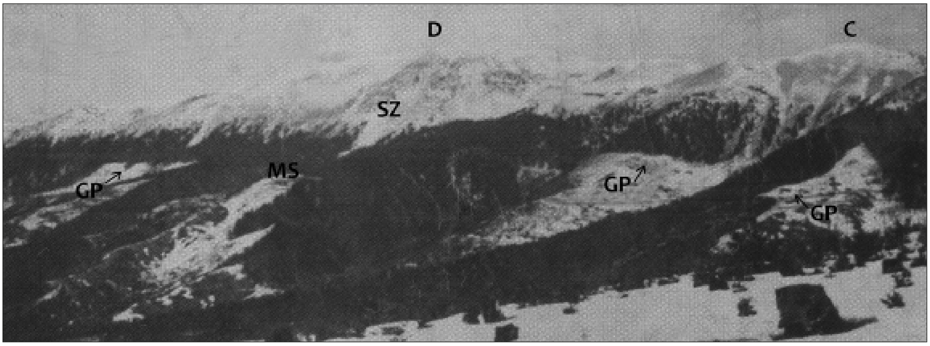

Photo 3. Vast deforested fragments of the northern slope of Babia Góra Mountain in the 1920s
C – Cyl (1,517 m a.s.l.), D – Diablak (1,725 m a.s.l.), GP – Górny Płaj tourist trail, MS – Markowe Szczawiny glade, SZ – Szeroki Żleb gully. Below Cyl summit, fragmentation of forest caused by avalanche paths which used to join deforested fragment of the slope
Source: Archive 2.

The avalanches that have passed down from beneath Cyl and Szeroki Żleb gully in the past, which continue today, and which reach the Górny Płaj trail have not caused great damage to it. The consequences of avalanches are visible as occasional fallen trees, which are immediately removed from the trail.

The large amount of avalanche activity on that part of the slope of Cyl which was used by shepherds has, since the 19th century, been accompanied by a degradation of the colluvium deposits on the slopes of the headwater area of the Cylowy Potok stream. The long debris flows documented in old paintings and photographs reached the height of the Górny Płaj trail at that time. Degradation of this part of the slope finally ceased when shepherding stopped on Babia Góra Mt. after the establishment of the Babiogórski National Park. At present only the accumulation sections of debris flows are visible in the field whereas their source areas were partly disguised by increasing regeneration of dwarf pine. It is difficult to find evidence to show the damage to the Górny Płaj trail by former debris flows in the neighbourhood of the Cylowy Potok stream. It is possible that the most intensive activity of debris flows in this area had already occurred before the tourist trail was established in 1883. The other area of the precipitous northern slope of Babia Góra Mt. located east of the Brona Pass was not subject to shepherding and therefore it was not possible for there to be an increase in the reach of avalanches in the past and a re-activation of debris flow associated with this.

Evaluation of the location of tourist facilities taking into account possible hazards rising from slope processes

The scale of the hazards arising from slope processes which may damage or destroy tourist facilities forms the basis for an evaluation of the proper location of operational, closed and planned facilities in the study area. Based on the very active slope processes discussed above, a 6-point scale was adopted for hazards (Tab. 1).

Tab. 1. Hazard scale for tourist facilities located on Babia Góra Mountain caused by slope processes and places of their occurrence. Location of tourist facilities (or their fragments) of and corresponding hazard levels are shown in Fig. 8

Hazard scale	Score	Causative factors	Place of occurrence
Lack	0	– facilities located beyond the range of intensive slope processes – colluvium creeping	– both functioning and closed tourist huts – past and proposed tourist facilities at the mountain summit – majority of sections of tourist trails
Minimum	1	– avalanches rarely reach tourist facilities	– section of Górny Płaj tourist trail below Szeroki Żleb gully – short sections of tourist trails below Sokolica and Brona Pass – section of Akademicka Perć tourist trail near Piarżysty Żleb gully
Small	2	– avalanches rarely exceed tourist trails – debris flows in the past	– section of Górny Płaj tourist trail in headwater area of Cylowy Potok stream
Medium	3	– mobile ground on the western side of Urwane deep-seated landslide including Kolista Polana glade. At present they are not hazardous to tourist trails but in the future they may be	– area at the northern and eastern sides of Markowe Szczawiny glade including Kolista Polana glade, where in the late 1960s a tourist hut and access road from Lipnicka Pass (Krowiarki glade) were planned
Large	4	– real risk of debris flows which increase their range – possible activation of deep-seated landslides, shallow-seated landslides and debris flows during the construction and use of cable cars, chair lifts and the access road to tourist hut – increasing range of avalanches on proposed ski trails	– section of Akademicka Perć tourist trail near the source section of the longest debris flow – proposed in the past tracks of cable car, chair lifts and access road to the planned tourist hut at Kolista Polana glade – planned in the past ski trails and ski lifts on the northern slope of Cyl
Very large	5	– constant growth of the Cylowa Zerwa a landslide since 1868, which may cause an increase in the range of avalanches and growing damage to tourist trails	– parts of the northern slope of the mountain including the surroundings of Brona Pass, headwater area of the Klinowy Potok stream wand the upper section of its valley

Source: authors' own study.

An analysis of the spatial range of hazards of various scales shows that on the greater part of Babia Góra Mt. tourist facilities are not put at risk by the very active slope processes (Fig. 8). Despite the varied landslide morphology of the slopes, the site where the now abandoned mountain hut was built beneath the summit of Babia Góra Mt., as well as the site in Markowe Szczawiny glade where a former mountain hut has now been replaced by a new one, are both considered to be probably safe. Taking into account ground stability, the summit of the massif, where operational tourist facilities were no longer being built in the 19th century and where the con-

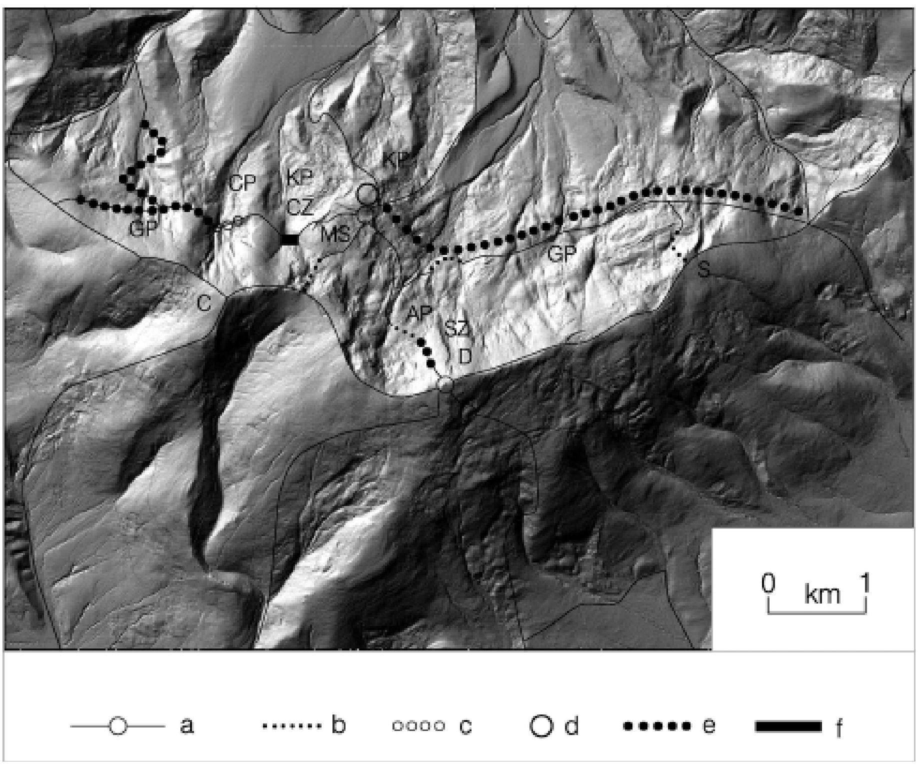

Fig. 8. Location of tourist facilities (or their fragments) and corresponding hazard levels (explanation of hazard scale is shown in Tab. 1)

Explanations: Sites with the following hazard intensity: a – 0, b – 1, c – 2, d – 3, e – 4, f – 5, AP – Akademicka Perć tourist trail, C – Cyl, CP – Cylowy Potok stream, CZ – Cylowa Zerwa landslide, D – Diablak, GP – Górny Płaj tourist trail, KP – Klinowy Potok stream (near CZ), KP – Kolista Polana glade (near MS), MS – Markowe Szczawiny glade, S – Sokolica, SZ – Szeroki Żleb gully

Source: authors' own study.

struction of new facilities has recently been planned, is also considered to be safe for tourist investments. The tourist trail running along the mountain ridge is not endangered from slope processes resulting in visible landforms despite the fact that on the northern side of the mountain and locally on its southern side, numerous landforms connected with deep-seated landslides occur. Also the tourist trails running from Zawoja to Górny Płaj and most sections of the trails going from Górny Płaj to the mountain ridge can be considered as stable. Also all tourist trails located on the southern slope of Babia Góra Mt. are visually stable along all their lengths.

The places where operational or planned tourist facilities are endangered by slope processes are located in the area of the precipitous upper part of the northern slope. These lie along some sections of the Górny Płaj trail which run along the base of this rock-fall and also in the environs of the Urwane landslide. Taking only operational and non-operational tourist facilities into account, the range and area where slope processes present a hazard to slope stability is much smaller. At present only a short section of Górny Płaj trail at Cylowa Zerwa landslide undergoes repeated damage. A short section of the Akademicka Perć trail near the headwall of the longest debris flow should also be considered as potentially the most hazardous section. The total length of these two sections of tourist trail represents less than 0.2% of the total length of all the tourist trails on Babia Góra Mt.

This evaluation of landslide risk exposure of the tourist infrastructure on Babia Góra is linked with efforts intended to prevent a mid-1960s project for a mountain hut on Kolista Polana glade below the Markowe Szczawiny glade. According to the plans this mountain hut for 100 tourists would be commissioned in 1970 and was going to be called the Lenin Hut. Implementation of this plan would have involved the demolition of the mountain hut in the Markowe Szczawiny glade (which was of value to Polish tourism in the Western Carpathians) and also the construction of a new road from Krowiarki glade to the new hut along the popular Górny Płaj tourist trail followed by the construction of a two-stage cable car from Górna Zawoja to the mountain summit (Diablak) or a chair-lift to the ridge above the rock-falls at Kościółki. Realisation of all these investments and in particular the road replacing górny płaj trail would have activated geomorphological processes destabilising these facilities (new landslides, longer reach of avalanches, debris flows). These arguments showing a real hazard associated with landslide movements in the environs of the Urwane deep-seated landslide did not bring the expected results. Professor Władysław Szafer, a distinguished scientist interested in the conservation of nature in Babia Góra Mt., was able to convince the investor to withdraw their plans to build this hut stating that the vibrations which would have occurred during the construction of the planned facilities, and especially while using the road, might have activated a large landslide on the ridge plateau called Izdebczyska. The level of risk was evaluated as very high, and it was declared that this landslide presented a real danger to the new hut. This was confirmed by a detailed picture of the relief of some parts of Babia Góra Mt. near Izdebczyska, Markowe Szczawiny glade and Kolista Polana glade (Fig. 4B: A2, A5, A6) where elements of landslide morphology may enlarge their dimensions or dislocate as a result of ground movement. Finally in 1969 the authorities withdrew proposals for the construction of the hut. In the following years it was easier to convince the originators of similar plans to construct tourist facilities on Babia Góra Mt. to withdraw their plans.

Evaluation of the vulnerability of tourist infrastructure to damage

The second element of the evaluation of hazards arising from slope processes affecting tourist facilities on Babia Góra Mountain is the vulnerability of individual tourist facilities to damage or destruction. The vulnerability of tourist buildings (shelters, huts) to damage depends, among other factors, on the type of building materials used. In theory wooden buildings in the area studied have been more vulnerable to damage than brick buildings. On the other hand, the losses associated with damage to or destruction of brick buildings (which have never occurred in this case) would have been larger. In the case of tourist trails, those which cross debris and clay mantle are more vulnerable to damage or destruction than those which cross blocks of colluvium, and the least vulnerable are trails running on a rocky surface. In the case of losses, the greatest occur on those which have modernised the pavement and also on trails which traverse slopes and have special stony ledges which stabilise the cut and embanked sides (like many sections of Górny Płaj trail). Among the past and present tourist facilities functioning on Babia Góra Mt., the most valuable is a new luxury mountain hut on Markowe Szczawiny glade which was built on stable ground, as shown by the history of the previous wooden mountain hut which had been located in the same place. The concern that this mountain hut faces potential destruction in the near future due to a re-activation of nearby deep-seated landslides must be seen as not very realistic. The opinions concerning such a hazard, which were expressed 50 years ago and were directed at preventing the building of a new mountain hut in the neighbourhood, were justified at that time by concern for the conservation of the nature of Babia Góra Mt.

The financial value of previously proposed tourist facilities (cable cars, chair-lift, ski-lift and ski runs, a mountain hut on the mountain summit) was comparable with the new mountain hut at Markowe Szczawiny glade. All the tourist facilities formerly proposed were planned to be built on slopes subject to landslides (except for the hut proposed on the summit). After forest clearance on this slope the reach of avalanches would have increased and debris flows would probably have developed. That is why these facilities should be considered as very vulnerable to damage or even destruction. This would have caused huge financial losses and shows that these unconsidered tourist investments present a very large risk of hazards.

Evaluation of the risk to tourist infrastructure

The risk to both operational and abandoned tourist facilities on Babia Góra Mountain resulting from slope processes is substantially smaller than was the case with the tourist facilities which were formerly proposed. This is connected with much greater costs that would be incurred during the construction and exploitation of new facilities situated in locations where there is a high risk of occurrence of slope processes. A high risk associated with the operation of new tourist facilities would be also linked to the necessity to undertake current maintenance to repair damage resulting from unstable ground. The risk associated with the operation of the mountain hut on Markowe Szczawiny glade should be considered as minimal due to the probable stable ground in its environs. Also the operation of tourist trails should be considered as a minimal risk due to the insignificant influence of slope processes or the lack of such influences, as well as the small costs of routine repairs to short sections of the trails. Only one short section of tourist trail (Górny Płaj) shows a high risk associated with its operation. It traverses the slope in the area of the Cylowa Zerwa landslide where every few years it is necessary to repair the paving on the trail and to stabilise its edge with special stone castings on the embankment side. A similar situation is going to occur on the short section of the Akademicka Perć trail in the neighbourhood of the headwall of a large debris flow which has increased in size since 2002. It is difficult to predict the moment of high risk in the operation of this section of the trail.

Discussion

The contemporary relief of Babia Góra Mt. is the result of the long-lasting impact of predominantly deep-seated landslides of Holocene age with older foundations (Łajczak 2014). The morphology of landslide slopes, the detailed analysis of which was possible using LiDAR data, shows a large similarity with landslides from other areas (e.g. Hutchinson 1988, 1995; Cruden, Varnes 1996; Dikau *et al.* 1996; Margielewski *et al.* 2008). The development of deep-seated landslides on Babia Góra Mt. is initiated either on the lower or the upper parts of the slope (Łajczak *et al.* 2014b). The first of these two situations is connected with headward erosion in headwater areas situated at relatively low altitude and so far it has not presented a hazard to tourist facilities as they are located at a considerable distance from these areas. However, negative impacts from such landslides should not be excluded in the future. On the other hand, the development of deep-seated landslides located on the higher parts of the northern slope occurs above rocky walls which are glacial undercuts and these are directed towards the crest of the ridge. Tourist trails crossing these areas are only locally affected by avalanches and debris flows.

Varied landslide morphology, especially on the northern slope of Babia Góra Mt., makes it appear that the ground is everywhere mobile and that rapid changes in slope morphology occur (Ziętara 2004). At present, the slopes of Babia Góra Mt., with some exceptions, are not modelled by very active geomorphological processes (Łajczak 2014; Łajczak *et al.* 2014b). Just on the northern slope and on a very local scale, the active forms include one deep-seated landslide, one shallow-seated landslide and four debris flows, while a large part of the slope is affected by avalanches. The analysis of numerous information sources (mostly unpublished) which are the basis of this paper shows that during the last 130 years, when the tourist infrastructure on Babia Góra Mt. was in a state of continuous development, repeated damage to a trail only occurred in one place on the northern slope of the ridge. This was caused by the creep of a thin layer of slope debris waste mantle. In some other places on the slope the influence of debris flows and avalanches was considered as a potential hazard to tourist trails.

The question which of the two combinations of factors, i.e. low frequency and high magnitude or high frequency and low magnitude of landslides poses a greater threat to the tourist infrastructure on Babia Góra Mt. can be answered indirectly by a comparison with other mountain areas where sufficient relevant information is available. Recently, there have been numerous reports on catastrophic deep and/or shallow re-activations of old landslide areas believed to be stable in the Polish, Czech and Slovakian flysch Carpathians (Klimeš *et al.* 2009; Klimeš, Blahůt 2012; Gorczyca *et al.* 2013; Pánek *et al.* 2013; Starkel *et al.* 2013). The re-activation of the Urwane landslide 150 years ago is a case of the reactivation of a deep-seated landslide, while the still active Cylowa Zerwa landslide is a shallow seated one. There is no available information about the frequency of occurrence and the scale of re-activations of deep-seated landslides elsewhere on Babia Góra Mt. prior to the development of shepherding (i.e. prior to the 17^{th}–18^{th} centuries) and certainly prior to the beginning of planned forest management in the early 19^{th} century followed by the first tourist facilities. Since then, any landslide-linked damage to pasture land, forests or the vicinity of tourist facilities have been recorded. The position of tree trunks, which typically are 200–300 years old, on the slopes of Babia Góra Mt. indicates that during that period the ground was stable. This means that landforms typical of deep-seated landslides which are common on Babia Góra Mt. underwent no apparent change during that time. Perhaps the impression that land sliding is common across the massif comes from the continued destructive effect of the Cylowa Zerwa shallow-seated landslide, but this is the only active landslide at this time and its impact is limited to a short section of a single trail. Indeed, the numerous stabilised debris landscapes on steep, formerly grazed slopes, and debris flows on such slopes suggest that this type of mass movement is diminishing following the removal of the debris mantle which is susceptible to displacement. On the other hand, on slopes containing large volumes of this material, i.e. beneath shallow landslides and debris flows, favourable hydrological and meteorological conditions may easily trigger a violent event in the once deposited material. Such events are reported from other flysch areas in the Carpathians (Klimeš *et al.* 2009; Klimeš, Blahůt 2012; Pánek *et al.* 2013). This is a potential risk on many sites on the northern slope of Babia Góra Mt. and the Górny Płaj tourist trail is particularly exposed to this action.

The information on "dangerous" landslides, which "frequently" occur in this area, and which is published in some books, papers and the press or even shown on information boards on educational paths in the Babiogórski National Park, is without basis. The same response concerns debris flows because only four of them, which developed in the 1997–2014 period, may be assumed to be active forms. On the other hand, avalanches on the northern slope of Babia Góra Mt. and which can locally reach tourist trails (Hudziak 1987; Łajczak 2004), and which used to cover larger areas in the past, are underestimated in the literature.

The existing and probable damage or destruction likely to affect tourist trails is limited to the parts of the slope covered with a thin layer of debris mantle where shallow-seated landslides and debris flows develop locally and to the small part of the slope covered with thick colluvium mantle where deep-seated landslides occur, but also involves outcropping bedrock. Avalanches, on the other hand, affect large areas of the northern slope. On Babia Góra Mt. an apparent contradiction occurs between a varied landslide morphology of slopes and ground stability hazards influenced by intense morphological processes. The ground seems more stable on slopes covered with thick colluvium mantle and this is where tourist facilities may be relatively safe. These slopes of varied morphology, in contrast to slopes of even profile with a thin waste mantle, are more stable. An analogous situation occurs in the case of contemporary high-mountain slopes operating in other areas, eg. in the Tatras, where torrential cones (debris flows) show the largest dynamics, whereas slopes covered with moraines are more stable (Kotarba 1992, 1997; Kotarba, Pech 2002; Rączkowska 2006; Rączkowska *et al.* 2012; Kotarba *et al.* 2013). The thick debris mantle on the slopes of Babia Góra Mt. is of different origin to that in the Tatras and re-activation of landslides on the slopes cannot be excluded, even in the near future.

The location of the operating and no longer-extant tourist facilities on Babia Góra Mt. seems to be more relevant in terms of ground stability than the location of facilities which it was planned to construct. One should emphasise the exceptional knowledge of and "feeling" for the terrain by the people who played a decisive role in choosing the location of facilities built in the 19th and 20th centuries. The fact is that the Scientific Board of the Babiogórski National Park and National Council for Nature Conservation did not accept the tourist investments proposed on Babia Góra Mt. in the 1960s, which were planned to be built in places potentially hazardous in relation to active slope processes and which were primarily aimed at respecting the nature conservation values of this massif. The opinions expressed at that time which stated that there was a large risk from landslides in the locations where tourist investments were planned were intended to add weight to this option.

Conclusions

1. The existing tourist facilities on Babia Góra Mountain should be considered as totally sufficient to meet the needs of tourism, because their further expansion would present a fundamental threat to the nature of the massif.
2. Currently active shallow-seated landslide and debris flows cannot be considered as processes typical of the dynamics of relief of the whole of Babia Góra Mt.
3. The evaluation of the magnitude of the risk to the tourist infrastructure on Babia Góra Mt. would be less optimistic if the expensive investments planned in the past had been carried out as they were to be built on the parts of slopes more vulnerable to geomorphological processes.

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