The summary of the doctoral dissertation
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The role of joints and faults in the formation of landslides and their scarps in the Silesian Beskids on the example of the region of Barania Góra.

The doctoral dissertation concerns issues related to the influence of the rock massif structure on the development of landslides in the Silesian Beskids. Its purpose was to determine the role of discontinuous basement structures (joints and faults) in the formation of landslides and landslide scarps in the source area of the Vistula River in the region of Barania Góra.

The conducted research covered the scope of structural geology, cartography and geomorphology, and their task was to perform field work and analysis of remote sensing materials in order to determine the extent of landslides and to collect data on the orientation and course of tectonic structures in their basement. The geological mapping of landslides have been made in a scale of 1: 10.000. Moreover measurements of the orientation of bedding planes have been carried out, as well as measurements and interpretation of tectonic structures (joints and faults) in outcrops. Nearly 3,800 measurements of the orientation of joints and bedding planes have been carried out, approximately 4,500 topolineaments and over 5,700 straight sections of landslide scarps were determined. These data were compiled and used as the input for further analyses. The following software was used for geometric, kinematic and statistical analyzes: MSExcel, Fabric8 and Orient. Maps plotted in Global Mapper, ArcGIS, and CorelDraw.

The research area covered the northern and western slopes of Barania Góra, the basement of which are the Upper Cretaceous formations (Santonian-Campanian) represented by sandstones and shales of the Upper Godula Beds (with the level of Malinowskie Conglomerates) as well as thick-bedded sandstones and conglomerates of the Lower Istebnia Beds (Campaniana-Mastrichtian). In terms of tectonics, this area is located within the Godula Thrust Sheet of the Silesian Nappe. Due to the block features of the basement structure, this area was described as the Silesian Beskid Block (Książkiewicz, 1972).

The research has shown that the orientation of the layers in this area results from their tectonic position in the upper, southern limb of the Szczyrk Anticline (with an axis oriented towards NE-SW). They rock strata dipping regularly to the SW and S at angles of the order of 10-25˚. In the bedrock the joint sets of the orthogonal system are most clearly visible. The T joint set is transverse (in relation to the orientation of the regional fold structures) and

shows the NW-SE direction, and the longitudinal joint sets: L, L 'and L" respectively: ENE-WSW, NE-SW and NNE-SSW. The sets of the diagonal system are less marked, and their directions are WNW-ESE (for the S_R set) and NNW-SSE (for the S_L set). The block tectonics of the basement is reflected in the form of numerous lineaments in the terrain, the course of which is usually consistent with the orientation of the orthogonal joint set. These directions are also characteristic of most of the faults identified. On the fault surfaces, most often transverse in the NW-SE direction, the presence of displacement indicators from various stages of deformation was noted. The original structures indicating a dextral strike-slip kinematics were overwritten with younger structures indicating vertical displacements. Normal-slip displacements are best marked along longitudinal faults in the direction of ENE-WSW and NE-SW. The largest fault zone associated with transverse faults runs through the central part of the area, and the accompanying discontinuous structures have been recorded on the Cienków ridge, in the Biała Wisełka and in the Kadłub valleys. In the top part of the Cienków ridge, a wide fault zone was also found with longitudinal dislocations. Some zones of discontinuous tectonic structures in the research area are revealed locally in the form of intense fracture zones along which landslide processes may appear (e.g. on the ridge of Barania Góra). They were considered to be hidden fracture zones.

The analysis of the topography has shown that the monoclinal structure of rock layers and the fault block structure of the basement referring to the directions of joint sets (primarily the orthogonal system) determined the arrangement of the river valleys network, the asymmetry of the slopes and the presence of steep morphological thresholds. The cataclinal slopes (directed towards S and SW) and orthoclinal (directed towards the W and NW) dominate in the research area. These dependencies made the cuestas of Cienków and Barania Góra stand out in the relief.

As a result of the research, 183 landslides with a total area of 13.75 km2 have been mapped, which constitutes 22.57% of the research area. The landslide of the slopes in this area is defined by the size of the landslides. About 50% of the landslide area is made up of 16 landslides; the size of each of those forms exceeds 0.5 km2. Among them, there is the Biała Wisełka Landslide Complex with an area of 2.24 km2 (16.31% of the landslide area).

The analysis of selected landslide groups and the interpretation of their geological structures allowed to determine their relationship with the basement. They are manifested by a clear overlap of the directions of topolineaments observed in the relief with the directions of structures in the bedrock outcrops. It was noted that the occurrence of landslides correlates with the maximum density of topolineaments.

The largest number of landslides developed consequently to the dip direction of the bedding planes, and most often they cover the entire surface of cataclinal and orthoclinal slopes.

The identified landslides are rocky and rocky-debris. Their characteristic feature is the straight course of landslide scarps, especially the main ones. Along such scarps, there are often tension cracks, and caves have formed in the collections of a dozen or so landslides. The direction of the scarps most often follows the course of the topolineaments parallel to the T, L and L orthogonal joint system.

In some landslides (the Kadłub Landslide Group and the Biała Wisełka Landslide Complex and the Polskie Kosarzyska landslide), scarps developed along the surface of longitudinal (NW-SE) and transverse (NE-SW and ENE-WSW) faults. They are then even several hundred meters long. The longest scarps (up to 700 m) were found in the Kadłub Landslide Group and the Biała Wisełka Landslide Complex. The heights of the scarps along of faults reach several dozen meters and they are steep. The highest scarps, 40-50 m high, were found in the Biała Wisełka Landslide Complex and in the Czerwony Usyp landslide on Barania Góra. Research has shown that particularly long and high scarps are characteristic of landslides developed in the thick-bedded Malinowskie Conglomerate and the Lower Istebna Beds. When these rocks are additionally underlying by thin-bedded rock formations (e.g. Upper Godula Beds), their disintegration takes place and blocks are formed. Based on the analysis of the geometry of the landslides, their location on the slopes and the course of discontinuous structures in the basement, it has been found that for landslides, the cutting surface of which resembles the course of faults or fracture zones, wide forms are typical. These are frontal landslides with detachment zones located in the upper parts of the slopes. Landslides of this type are also the largest in size and most often developed on outcrops of the Lower Istebna Beds.

The research has shown that almost all landslides in the Barania Góra Range are of structural control, and the nature of their movements is compound. They are an expression of the post-tectonic relaxation of the rock massif. Often, landslide processes occur parallel to the axis of the maximal principal paleostress ($\sigma 1$). Nowadays it is the axis of minimum stress ($\sigma 3$) but displacements are opposite. Within most of the landslides, translational and rotational displacements have been found. Analyses of the landslide relief and slip surface shapes have shown that the rotational slides prevail over the translational slides. Rotational displacements are more common on their own and are usually found in landslides developed in the Upper Godula Beds. Translation slides are typical for thick-bedded formations (Malinowskie

Conglomerate and Lower Istebna Beds) and are usually an element of compound movements. The compound nature of the displacements results from the change of translational movement into rotational one, which was most often caused by lithological changes of the landslide bedrocks. The underlying thin-bed formations were more susceptible for shearing. The pressure of sliding rock packets on the rocks in the lower parts of the slopes caused folding and thrusting of rock masses. Such deformation structures have been found in the toes of landslides. The comparison of this information with the geometry of the frontal landslides allowed to distinguish "drawer structures" and present a model of their development.

In the final part of the dissertation all landslides have been classified on the basis of the movement mechanism. According to criteria after Varnes (1978); Dikau et al. (1996) and Grabowski et al. (2008) most (approx. 70%) of landslides in the study area have been classified as the compound types. The rotational slides are the second type (17-18%) and the translational slides come third (9-10%). In another classification, proposed by Hungr et al. (2014), 39% of landslides represents the rock slope deformation and 33% the rock compound slides. The rock rotational slides constitute 10% of landslides and the share of other types (including complex types) does not exceed 7%.

The research based on field work and remote sensing analyses allowed to determine the main structural directions in the area with monoclinal and fault block structure of the basement and determine their relationship to the jointing. The analysis of remote sensing materials made it possible to refine the data related to discontinuous tectonics, especially when determining faults. The block structure of the basement had a significant impact on the relief of the research area. The presented research results confirmed the significant role of passive factors in the development of landslides in the Silesian Beskids. A clear relationship has been found between landslide scarps and faults. This relationship is most evident in a detailed study of the Biała Wisełka Landslide Complex and the Polskie Kosarzyska landslide.