SLOVAK GEOLOGICAL MAGAZINE

Geodynamic Development of the Pokoradzská tabuľa Plateau

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Abstract: The character of the recent relief of the Pokoradzská tabuľa Plateau was determined close after the deposition of the volcanoclastic Pokoradz formation in the late Miocene. The most intense evolution of block rifts and fields as well as landslides occurred in the Early and Middle-Pleistocene, mainly due to relative uplift of the area and subsequent lateral erosion by the streams. The youngest landslides originated in Holocene and some older landslides revived are active even at present, and, both with the gully erosion they are the most remarkable geodynamic phenomena of the area. A part of them represent the older landslides which were reactivated due to improper construction and agricultural impacts.

Key words: landslides, gully erosion, karst, tectonic activity

Introduction

The Pokoradzská tabuľa Plateau situated in the middle part of southern Slovakia represents a transitive type of the area between the Revúcka vrchovina Upland and the Rimavská kotlina Basin. The major part of the plateau consists of volcanoclastic Pokoradz Formation which overlies the molasse sediments of the basin, or, in the northernmost part of the area where the volcanoclastics overlie the Paleozoic and Mesozoic rocks of the Slovenské rudohorie mountains. In the tiny part of the area, on its N and NE margin, this basement rise up to the surface.

The relief of the area has the character of a gently dissected plateau elongated only in its central part in the N-S direction. On its south margin and in the vicinity of the main valleys of Rimava and Blh rivers the area is more intensively dissected by tributary valleys and by slope failures and by gully erosion. Karst phenomena are present in the NE part where carbonate rocks occur.

The geologic-tectonic development and the structure of the area have been described in detail in the publication of VASS et al. (1986). A more precise research was carried out for the purposes of the investigation of the geodynamic development of the area (mainly of slope gravitational failures) (DEMJÁN et al.,1990). In the scope of this work the authors of this paper studied the area of the Pokoradzská tabuľa Plateau.

Pre-Quaternary development of the area

The oldest rocks of the area studied are Devonian lydites and graphitic phyllites (with layers of meta-rhyolite tuffs) of the Gelnica group occurring in the northern part of the area (Fig.1). Here they are overthrust above the phyllites and graphitic phyllites with layers of metamorphosed sandstones and conglomerates of the Carbonian Dobšiná group. Permian rocks have not been preserved. Triassic rocks are represented by sandy-clayey shales with layers of evaporites and marlstones and to a lesser extent by marly shales or limestones. These were (Silica nappe) overthrust over the Upper-Triassic limestones (locally hornfelsic), which, in the NE part of the area, are present in the form of a nappe inlier. The Jurassic rocks have not been preserved. Intense tectonic movements were active in the Cretaceous and the above mentioned nappe structure was formed.

During the Paleogene - up to the Kiscelian - the tectonic uplift of the area continued and weathering as well as karst process took place. The major part of the Rimavská kotlina Basin was flooded by sea in the Kiscelian. The thickness of Kiscelian sea sediments reaches from several meters up to tens of meters, but in the area studied they are covered by younger Tertiary sequences. At the end of the Kiscelian period the sea in the N part of the basin retreated and denudation and weathering took place. A new subsidence and transgression occurred in the Egerian. In that time the sediments of the Lučenec Formation were deposited. The formation is composed mainly of calcareous silts and siltstones

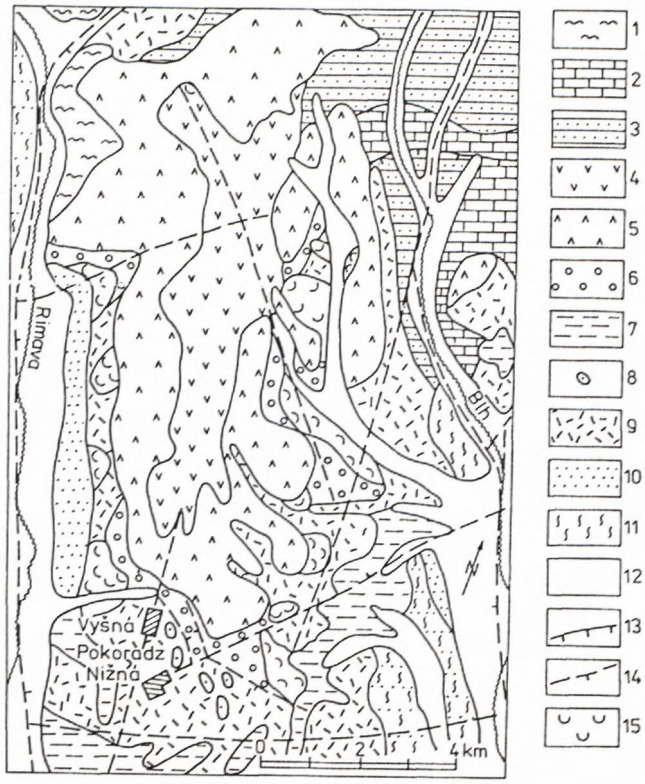

Fig.1 Geological map of the Pokoradzská tabuľa Plateau. 1 - phyllites, 2 - limestones, 3 - shales and sandstones, 4 - block rifts - plateau, 5 - dissected block rifts, 6 - block fields, 7 - clayey-silty sediments, 8 - rests of volcanoclastics on the hill tops, 9 - slope debris, 10 - terrace sediments, 11 - loess, 12 - flood plain deposits, 13 - overthrusts lines, 14 - faults, 15 - landslides

with layers of clays and sands. The thickness of the formation reaches several hundreds of meters. Towards the end of the Egerian regression took place and sedimentation continued only in the southern part of the basin. The next subsidence occurred in the Middle Miocene (Badenian, Sarmatian), connected with the deposition of partly lacustrine, partly terrestrial sediments of the volcanoclastic Pokoradz Formation, with a total thickness of 100 to 150 meters. The formation is composed of epiclastic volcanic sandstones, conglomerates and of volcanic breccias, which build the uppermost part of the formation. There followed the denudation of the volcanoclastic formation resulting in the reduction of the extent of the volcanoclastics.

The Tertiary sediments are tectonically dissected into blocks by two dominant perpendicular fault systems of NE-SW and NW-SE direction. Faults of N-S and E-W direction are to a lesser extent also present. The system of NE-SW direction is the older one and it dissects syngenetically the majority of Kiscelian and Egerian sediments. The NW-SE direction fault system was formed during the Badenian (VASS et al., 1986). Differential movements along the majority of faults occurred up to the end of the Neogene, some of them were active also in the Quaternary. During this time two periods of calm subtropical conditions resulted in the grading of the terrain. In the Pannonian a midmountain erosion level was formed. Its relicts are found in the altitudes of 470 to 530 m. In the Upper Pliocene, so called "riverain" plain developed - its very rare relicts are found in the altitudes of 330 to 350 m.

Excluding the exception of two smaller faults, other faults dissecting the Pokoradz Formation have been mentioned in publications. In the scope of our research several such faults have been found, based on the study of relicts of the midmountain erosion level and of the shifted basement of volcanoclastics, both from direct field observations and from structural boreholes.

Geologic and geomorphologic development during the Quaternary

In the Quaternary a revival of tectonic movements occurred. The upheaval in the entire area followed, but with a more intense process in the northern part. As a result of this uplift, together with climatic changes in the Pleistocene, there were alternating phases of river erosion and accumulation. In a more extended area 7 or 8 terrace benches have been formed (Donau-Würm) differing from the present flood plain altitude from 1 up to 105 m (PRISTAŠ in VASS et al., 1986). In the area studied, 3 terrace benches corresponding to the Mindel-Würm, with the base maximum 30 m above the flood plain level, have been found. Lithologically, sandy gravel sediments prevail.

The origin of proluvial deposits is closely connected with the above mentioned development. They are of similar composition as the terrace sediments. The youngest Holocene proluvial cones are prevailingly loamy or loamy-sandy, like the alluvial plain sediments. The terrace sediments are mostly covered by loess and loess loams with the thickness from 2 to 8 m (as a rule, greater thickness is developed on the older terraces).

Slope sediments have varied lithologic composition and thickness depending on the character of substratum, morphologic position and geodynamic development. On the slopes built by volcanoclastics and within the bodies of block fields loamy-stony, rarely stony debris are common. Considerable thicknesses (10 to 15 m) are frequent mainly in block

fields, at the bases of slopes and in some sliding areas. Similar debris, however not so thick, overburdens the slopes built by Paleozoic and Mesozoic rocks. Loamy debris overlies the Egerian fine-grained sediments or Mesozoic shales.

Recent geodynamic phenomena

The geologic, geomorphologic, climatic and other natural conditions together with human impacts create the conditions and factors for the genesis and development of various geodynamic phenomena. The most important among them are slope gravitational phenomena, gully erosion, recent neotectonic activity of the area and karst.

Slope gravitational phenomena

In the area studied this type of the geodynamic factors is represented mainly by block rifts, block fields and landslides of various types, age and activity. Surficial creep of debris or falling of fragments and blocks of rocks are developed to a lesser extent.

Block rifts are developed in the whole range of the area, were the volcanoclastic Pokoradz Formation overlies the relatively softer plastic sediments of Lučenec Formation. In the northern part of the area with volcanoclastic rocks overlying the pre-Tertiary semisolid rocks, this type of slope failures is rather rare.

The orientation of single blocks is derived from the two main tectonic systems - NW-SE and NE-SW. Deviations converging to W-E and N-S occur from place to place, corresponding to the regional tectonics of the area. The dimensions of single blocks range between tens and hundreds of meters. The difference in the base level of blocks does not exceed 20 m, in majority of cases it is 10 to 15 m, and does not exceed 10% of their thickness.

The landscape of the block rifts depends on the geomorphologic position of their individual parts. The marginal parts of the plateau are characterized by steep and well dissected slopes, even with stony walls and pillars based on main tectonic faults of the area. The majority of these morphological forms represents the settled walls of single blocks which, at present, actively affect the foreland of block rifts. The central parts of the block rifts are prevailingly smaller plateaus and gentle slopes with thin debris cover.

The relatively extensive development of block fields was based on the tectonic and gravitational dissection of the Pokoradz Formation during the tectonic uplift of the whole geological structure and on the vertical river erosion. Generally in the tectonically predisposed valleys of NW-SE direction the erosion level reached more than 100 m deeper than the volcanoclastic base present. During the geomorphologic development this base was undercut by other streams. Thus conditions were created not only for vertical movements of blocks, but also for their horizontal slips and the formation of block fields.

Typical and rather extensive block fields were formed mainly in areas with sufficient height difference between the volcanoclastic base and local erosional base, where the length of slopes was sufficient. Generally, the complete succession of slope failure, e.g. block rifts - block fields - landslides (Fig.2 and 3) occurs under these conditions. From place to place, the dimensions of blocks range from a few meters up to 100 m. Blocks with dimensions reaching some hundreds of meters are rare. The maximum length of block field 1 km eastwards from Vyšná Pokoradz is approximately 1500 m.

Some morphologically active blocks on slopes consist of solid rocks and are covered by a thin layer of debris, or in some places they even emerge in natural outcrops. The majority of blocks is composed of intensively deteriorated and weathered volcanic rocks.

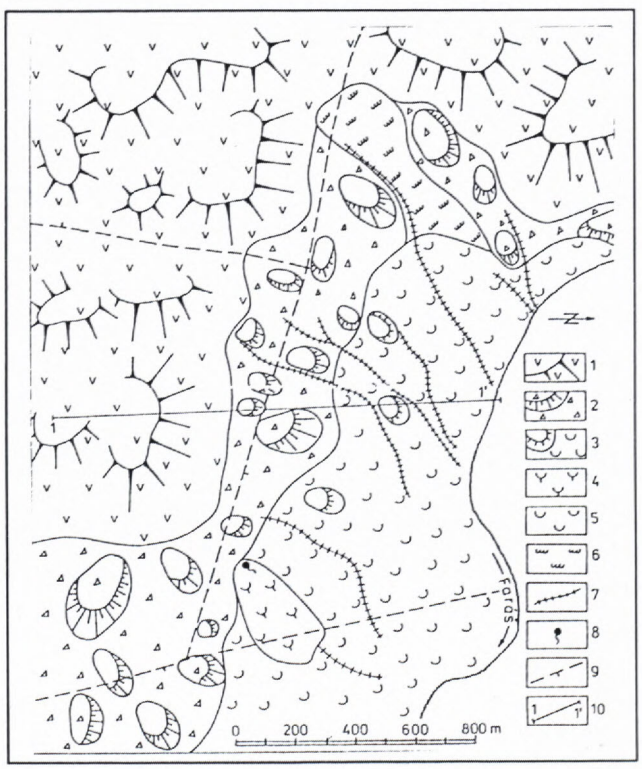

Fig.2 Landslide area on the right slope of the Faráš valley. 1 - block rifts, 2 - block fields, 3 - blocks of volcanoclastics in landslides, 4 - active landslides, 5 - potential landslides, 6 - stabilized landslides, 7 - erosional gullies, 8 - springs, 9 - faults, 10 - line of the cross-section.

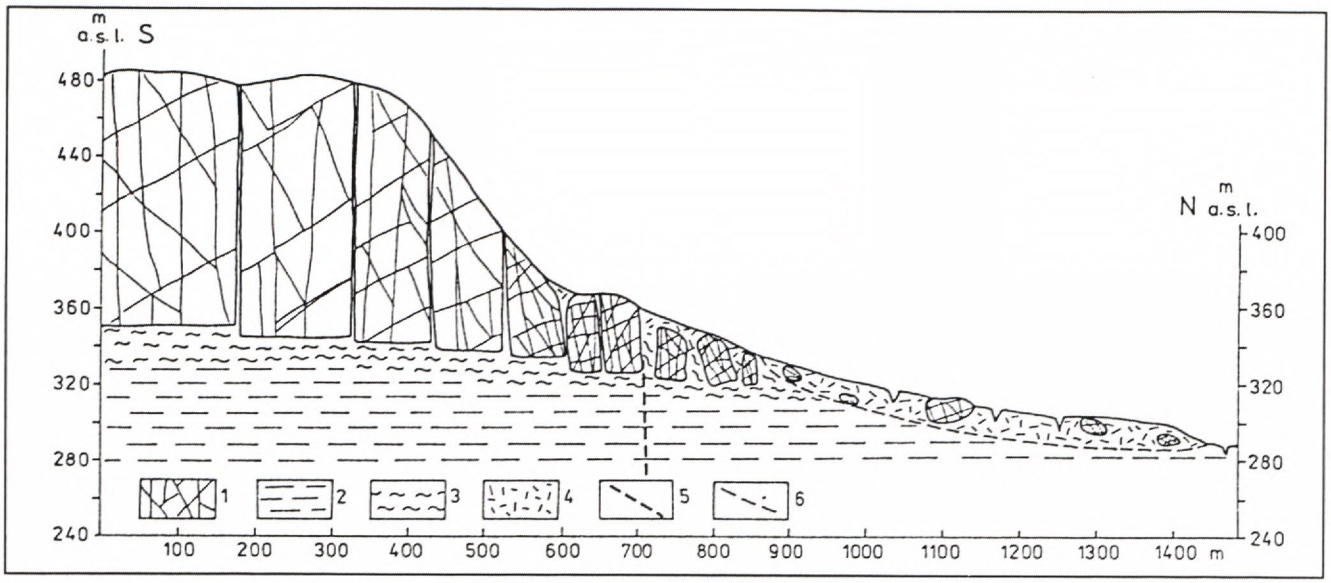

Fig. 3 The cross-section of the gravitationally disturbed slope near the Horné Záhorany village
1 - blocks of volcanoclastic rocks, 2 - clayey-silty sediments, 3 - clayey-silty sediments disturbed by squeezing, 4 - slope debris, 5 - fault, 6 - slip surface

Such blocks do not usually have active geomorphological features.

Block fields developed in an area of about 12,8 km^2 (approximately 10 % of the total area) are partly covered by forest, partly by meadows and grazeland. They do not represent any danger for engineering structures or to the environment. Nevertheless their loosen structure enables the infiltration of surficial waters and groundwaters waters into greater depths. This fact is important for activation of landslides in their foreland.

Landslides cover nearly 4 km^2 of the area, among which the active ones represent 1 km^2. Areal landslides are the most common type, the frontal ones are less frequent. Stream-like landslides, or earthflows are very rare. Depending on local conditions the total area of individual landslides reaches from several m^2 up to several thousands of m^2. The largest sliding area (nearly 1,5 km^2) is developed on the right bank of the stream Faráš, NW from the Horné Záhorany village (fig.2).

Landslides occur mostly on the periphery of block fields, some of them are in block fields or on the margin of block rifts. In both cases the sliding masses are composed of loamy-stony or stony-loamy debris usually containing isolated blocks of volcanic rocks. The underlying stratum is composed mainly of clayey-silty Lučenec Formation layers. They are practically impermeable and this feature together with their physico-mechanical properties enables the movement of sliding masses down the slopes.

Landslides developed in the area built by block rifts are less frequent. In this case shearing planes are developed either in the Quaternary sediments or on the boundary plane between Quaternary sediments and volcanoclastic rocks.

The thickness of landslides ranges from 5 to 15 m, occasionally it reaches up to 20 m. Greater thicknesses are typical for slides situated on the margins of block fields, mainly when the sliding masses comprise blocks of volcanoclastics.

Sliding of debris on Triassic and Paleozoic schists or of loamy debris overlying Lučenec Formation is very rare. Their thickness is up to 7 m.

Stream-like landslides or earthflows occur mostly within the active landslides, sometimes within the potential landslides. Several earthflows were formed in local terrain depressions with greater thickness of saturated slope debris.

Surficial creep of loamy debris is typical on relatively steeper slopes (6 to 12) formed by the sediments of the Lučenec Formation. Typical forms are characterized by gently undulating relief and several scars. This type of slope failure is caused by weathering of the clayey-silty Egerian sediments, which have comparatively higher shear strength than the weathered cover of loamy character and are able to keep steeper slopes better than the loamy debris.

The impact of landslides on the environment of the Pokoradz Plateau is negative. Frequently they damage meadows and pastures, forests and agricultural soils are less affected. Several failures

endanger roads, mostly in the vicinity of Lukovištia and Ostrany villages.

Falling of fragments and rockfalls

This type of gravitational slope movement occurs mainly on steep slopes with frequent rock pillars and rock walls. This phenomenon is less common in the area of Mesozoic carbonate rocks.

The most frequent is falling of fragments with subsequent development of stony debris and talus. Toppling and falling of single blocks or walls resulting in rockfalls occurs rarely.

These phenomena can be seen mostly on the slopes built by volcanoclastic rocks, less frequently on slopes with Triassic carbonate rocks.

The development of slope gravitational phenomena

Based on the analysis of the geologic and the geomorphologic conditions we may conclude that the initial disintegration of rock masses formed by volcanoclastic rocks began very soon after their formation. At that time the clayey beds of the Lučenec Formation were insufficiently consolidated and thus they were very easy to deform under the load of volcanoclastic. The old networks of faults were copied due to these gravitational movements. Further excessive development of block rifts and locally block fields followed due to the erosional dissection of the midmountain paleoplain and mainly riverain level when the base of the Pokoradz Formation had been undercut. The most intense development of block fields and the creation of recent block rifts structure followed in the Late Pliocene and in the Early Pleistocene, when the vertical erosion reached the basement of volcanoclastics in the tributary valleys.

Landslides developed subsequently to the formation of the block fields. The oldest generation was formed in the Pliocene above the riverain level. Important development of landslides occurred in the Early Pleistocene during the intense tectonic upheaval of the area when extensive vertical erosion of streams took place. Most of the landslides of this age are recently stabilized.

Younger landslides are connected with the incision of the erosional level during the Interglacial Mindel/Riss. They are at present mostly stabilized or they are potential at present. The youngest landslides are related to the last phase of the incision of streams - from Riss to Würm. In several lateral valleys some new landslides have been formed during the Holocene period. Some of them are active up to now. However, in the scope of the geomorphologic development during Younger Pleistocene and Holocene, several older landslides have been activated. In most of the cases this activation took place close to the contact of the volcanoclastics in the block rifts or block fields with the underlying sediments of the Lučenec Formation. The triggering factor were the abrupt changes in climatic and/or hydrogeologic conditions. The precipitation waters penetrating the volcanic rock masses are drained by springs on the top of impermeable beds of the Lučenec Formation, or they are dewatered through the debris in their foreland. In the case of extreme precipitation, old landslides can be activated. An example of such failure can be seen NE from Horné Záhorany, in the valley of the stream Papča (Faráš, Fig.2). The activation of the older landslides or the initiation of the new ones occur also due to human impact. This was observed mainly in the case of undercutting of slopes in road cuts or by improper agricultural practices of the area.

Gully erosion

The most important occurrences of gully erosion are related to the tectonically deteriorated and weathered Triassic shales, at the lithological contact of the pre-Quaternary rocks with different sensitivity to erosion, and to the slope sediments failed by slope movements.

The erosion of the pre-Quaternary rocks is well developed in the northernmost part of the Pokoradzská tabuľa Plateau, within the area formed by Lower-Triassic shales. The undisturbed shales are relatively resistant to weathering. But, in the tectonically failured parts of the rock masses, their resistance is reduced. Weathering penetrates very deep into the mass and enables an intense development of gully erosion.

The average depth of gullies formed on shales ranges from 10 to 12 m. From their V-shape and the extensive lack of the vegetation cover it is evident, that the process of gully erosion is active at present. The orientation of gullies conforms to the main tectonic directions NE-SW and E-W. The greater gullies with a length of 700 to 800m are often drained by small streams and lateral erosion creates conditions for the initiation of small failures of slope sediments.

The rocks with different sensitivity to erosion create another possibility for gully erosion. Some smaller gullies occur at the contact of volcanoclastic rocks and carbonates or at the contact of volcanoclastics with slope debris.

Gully erosion occurs in the Quaternary deposits mainly within the landslide bodies. The gullies in active landslides are relatively shallower and shorter

than others. The presence of gullies influences the stability regime of the landslides. In active landslides, the shallow fresh gullies enable the supply and penetration of surficial waters into their bodies leading to a decrease of passive forces and increase of active forces resulting in mass movements. The gullies within potential landslides have gentle slopes with a vegetation cover and are rather deeper then those within active ones. Usually, they are able to drain sufficiently landslide bodies, so that activation of potential landslides takes place only in the event of extreme precipitation.

Karst phenomena

The karst is developed only in the NE and northernmost margin of the area studied. The NE margin of the Pokoradzská tabuľa Plateau is confined by 4 km long allochthonous Blh river canyon -shaped valley. Westwards from Blh river there is a narrow strip of carbonate rocks with occurrences of a lot of karrens and several karst pits is developed. The karst phenomena are formed on the chemically pure biogenic and Wetterstein limestones. The diameters of karst depressions reach up to 150 m. Their occurrence together with karrens is related to tectonic jointing and to the subsequent dissolution of rocks.

Fluviokarst forms are represented by so called "dry valleys", for instance the Maruškin jarok Brook on the right side of the Blh River. The valleys begin in the Triassic shales or in volcanoclastics, and at the contact with carbonate rocks, surficial waters sink into the ground. An inactive cave with a length of 35,7m was created in the mouth of the Maruškin jarok Brook valley.

Tectonic activity and seismicity of the area

According to precise geodetic measurements, the intensity of recent vertical movements does not exceed 0.5 mm per year (MARČÁK in VASS et al.,1986). Positive anomalies are related to the northernmost part of the area, negative ones to the southern margin of the area studied.

Obviously, similar activity took place during the whole Quaternary period, during the prevailing uplift of the area. Deducing from the depth of the Quaternary incision of the valleys, the average value of the uplift was approximately 0.1 mm per year. The uplift was not uniform. During the formation of terrace deposits, the value of uplift could reach up to 3 mm per year.

The differential Quaternary movements along fault planes occurred mainly on the N, NW and S margin of the Rimavská kotlina Basin. Within the Rimavská kotlina Basin the movements along the NW-SE and N-S directed faults were the most frequent ones, for instant in the valley of the Rimava or Blh rivers (Fig.1). It is supported by the asymmetric distribution of the river terraces, which occur exclusively on the sunken blocks (PRISTAŠ in VASS et al.,1986).

The seismic activity of the area is rather low. According to various sources 5 earthquakes with intensity of 4° MSK were observed during the last hundred years. The most intense one was the earthquake near Dulovo (Blh river valley) in 1956 with an intensity reaching 5° MSK.

According to the current seismic activity and Quaternary vertical movements we can expect movements (in spite of not very convincing results of geodetic measurements) along the faults of mainly NW-SE direction and/or along the boundaries of the Pokoradzská tabuľa Plateau with adjacent geomorphologic units.

Conclusions

Relatively intense tectonic movements are typical for the geodynamic evolution of the Pokoradzská tabuľa Plateau from the Paleozoic up to the present, together with extensive gravitational deformations which took place from the Late-Miocene up to now. The whole volcanoclastic Pokoradz Formation is gravitationally deteriorated into blocks of various dimensions sunken deep into the underlying relatively plastic layers of the Lučenec Formation. These clayey-silty sediments are squeezed to the foreland of block rifts, moving some blocks of volcanoclastic rocks down the slope. Due to this mechanism, vast block fields have developed. Along the margins of some block rifts, but mainly block fields, numerous landslides of various dimensions and shape occurred. They damage and/or jeopardize the environment, mainly meadows and pastures, locally marginal parts of municipalities. In addition to extreme precipitation anomalies and gully erosion improper interference with the landuse, mainly grazing of pastures by cattle or undercutting of slopes, can be a triggering factor for development of slope deformation. Experience with surficial and deep dewatering (horizontal boreholes) proved that these remedial measures provide very good results in decreasing or stopping of the sliding activity.

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