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THE ROLE OF EXPANDING CLAY MINERALS IN MASS MOVEMENTS AT HOLLÓHÁZA, TOKAJ MTS.

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ABSTRACT

Hollóháza is situated in the NE part of Hungary, in the Tokaj Mts. region neighbouring Slovakia. Hollóháza is surrounded by remnants of the former trenches of a ring-shaped Miocene volcanic caldera, 4-6 kilometres in diameter. The village settled down in the natural cirque of the former caldera. Here rhyolite tuff and clayey marine sediments of various thicknesses (10-20 m) and volume (< 20 km^3) are deposited on the andesite basement. The watershed rising over the village is contoured between 250-600 metres. The inner area is about 20 km^2, into which yearly approx. 12 mill. m^3 water quantity infiltrates and runs down to the catchment area of Török stream. The average annual precipitation is 600-650 mm. The rhyolite tuff of various grain size originally fallen into water alternates with Sarmatian marine clays and has been strongly altered. The covering soil has high clay mineral content, too. Andesitic rocks in the basement have also been transformed into clay minerals, strongly contributing to the occurrence of sliding. All these geological formations may cause different mass movements due to their high swelling clay mineral content.

Key words: Miocene, volcanic caldera, marine clay, altered rhyolite tuff, altered andesite, landslides

INTRODUCTION

Hollóháza is situated in the Tokaj Mts. region, NE Hungary, neighbouring Slovakia. This is a potential area for mass movements which comes from the characteristic geological structure of the mountains. There were several unfortunate examples in the recent past for showing the real nature of this phenomenon.

The area of the Tokaj Mts. has been the part of a former volcanic archipelago, constantly sinking in the Middle-Upper Miocene between fault lines stretching along the Hernád and Ronyva streams (NE – SW, NW – SE). The volcanism was calc-alkalic which resulted in rhyolite-rhyolite tuff and later in andesitic-dacitic and basaltic-andesitic lavas and pyroclasts, in two cycles during the Badenian and Sarmatian stages (Gyarmati 1977, Ilkeyné Perlaki and Pentelényi 1976).

Hollóháza is surrounded by the remnants of the former ring-shaped walls of a Miocene volcanic caldera, 4-6 kilometres in diameter (Fig. 1). The heights of these peaks of the watershed are rising over the village by 250-300 metres, at 500-600 metres above sea level. The inner area is about 20 km^2. It is the catchment area of Török stream into which approx. 12 mill. m^3 water quantity infiltrates and runs down on an average of 600-650 mm annual rainfall. The rainwater flows towards the village from all directions down the steep slopes, partly as surface water flow and discharge from the aquifers, partly as ground water.

The village settled down in the natural cirque of the former caldera. Here the basal andesite is covered by rhyolite tuff and clayey marine sediments of various thicknesses (10-20 m) and volume (< 20 km^3). On their border, aquifers discharge on the valley bottom. The cirque-like depression is cut by a huge tectonic valley directed from NW to SE, showing lateral movement (Török stream valley).

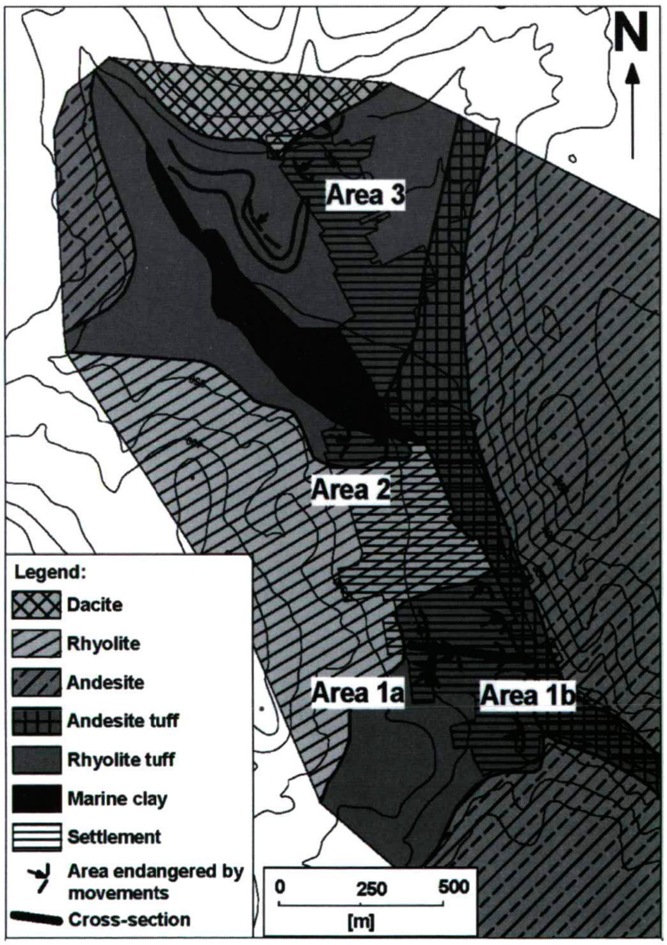

Fig. 1. The uncovered revised geological map of the Hollóháza area.

In the SE it breaks through the rim of the former caldera forming a gorge. Clay and rhyolite tuff layers dip by 10 – 25 ° from east and west towards the tectonic valley (Zelenka and Trauer 1999a, 1999b, 2003, Fig. 1 and Fig. 2).

The rhyolite tuff of variable grain size alternates with Sarmatian marine clays. It has originally fallen into water and has been strongly argillised. The covering soil ("nyirok") has a high clay mineral content, too. These rocks swell in contact with water and slides may occur on their surfaces. Andesitic rocks in the basement are also highly altered to clay minerals, strongly contributing to the occurrence of rotational slumps.

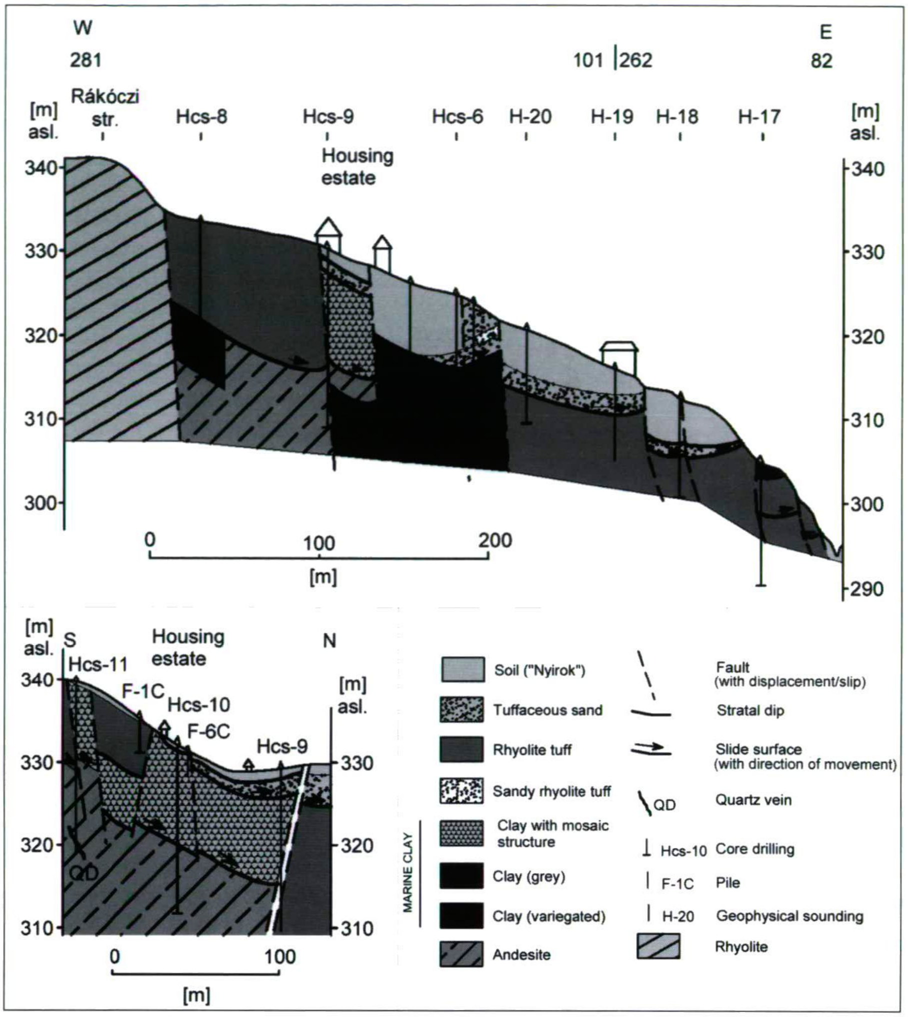

Fig. 2. Geological sections of the József Attila residential area. The directions of the sections are shown in Fig. 1.

Methods

In the research program studying the areas affected by landslides we used the following methods:

- geological survey mapping surface rock outcrops, stream outcrops, aquifer fissures and the direction of ant-hill rows,
- aerial photo interpretation of movement benches of the drainage pattern,
- surface geoelectric (resistivity) survey of the position of rock bodies,
- engineering geophysical sounding for the determination of stability, gamma activity, density and water content of rocks,
- core drillings, soil mechanical spiral drillings for the determination of petrologic and soil mechanical characteristics like plasticity and flow limit, shear and compressive strength,
- mineralogical analysis of the different affected rocks. The mineralogy of the samples was determined by X-ray diffraction and thermal analysis.

The X-ray diffraction analyses were done by Philips PW 1730 diffractometer under the following conditions: Cu anticathode, 40 kV and 30 mA tube-current, graphite monochromator, goniometer speed 2 °/minute. The mineral composition was calculated on the basis of the relative intensity rates of characteristic reflections of the minerals, applying thepublished or experimental corundum factors of minerals.

The thermal analyses were made by Derivatograph–PC with simultaneous registration of TG, DTG and DTA curves using corundum crucible, with a heating speed of 10°C/minute up to 1000 °C and with Al_2O_3 as inert material. The quantitative determination of the thermally active minerals is based on stoichiometric calculation of the heat-induced decomposition process of the minerals identified. The calculation is based on the measured loss of mass during the analysis.

In this paper only the results of the geological and mineralogical investigations are discussed. Results of other methods are presented in the reports cited in the Introduction.

Damages caused by land movements at Hollóháza

Different slides can be rotational slumps, slumps and bed slides morphologically causing serious damages to buildings, road and public utility networks (linear infrastructure). Inside the village, there are no mass movements in the upper part of Rákóczi road and near the Porcelain Factory because there are massive lava rocks. Other parts of the village are settled Sarmatian clay of mosaic structure alternating with rhyolite tuff. These formations are highly slide hazardous due to the presence of swelling clay minerals and play an important role in the damaging movements on the surface.

Land movements are of different size. 11 potentially hazardous areas can be delineated in Hollóháza, from which the most dangerous are (1) the surroundings of Attila József residential area, (2) surroundings of the Roman Catholic Church and (3) the southern slopes of Nagy Hrabó Mt.

Areas 1/A. and 1/B

In the area of housing estates in József Attila Street rock mass of 2.5 mill. m^3 moved towards SE on the boundary sheet of Sarmatian clay and rhyolite tuff. This movement affected more than 50 flats. There were scissor-like openings on the concrete walls of the houses. In brick houses damages were mainly due to displacement of fences and walls by several 10 centimetres along surface outcrops of rotational slumps. Here the walls cracked first, than insufficiently fixed fences tumbled down, in the end detachment along cracks on sides of flats and collapsing were observed.

Fig. 3. Front of a landslide in József Attila residential area.

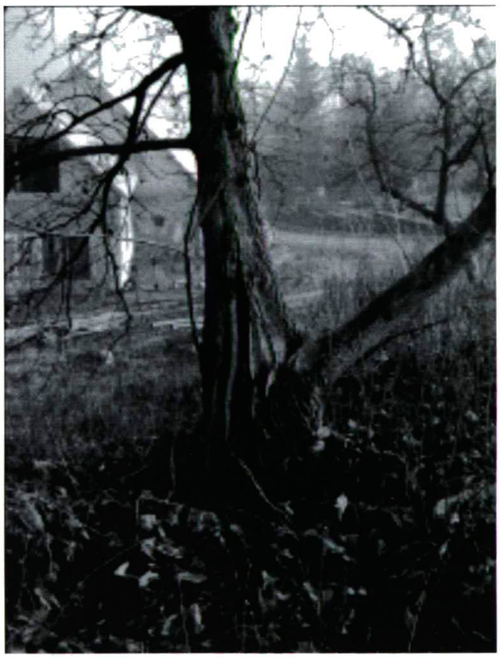

Fig. 4. Fractured tree in the József Attila residential area.

Area 2

In the vicinity of the Roman Catholic Church and its surroundings in Ady Endre Street rock mass of 0.3 mill. m^3 moved. There were slides and slumps on the boundary between the rhyolite tuff and Sarmatian clay due to permeation of water from the water channel. The movement of Sarmatian bentonitic grey clay and variegated clay has damaged the rock dam of the stream bed. A 6 metres deep drainage pit helped to stop the bed slide. There is in average a 12 litres/minute water output from the tapping. The area has been stable for a year.

Area 3

Rock mass of 1.5 mill. m^3 moved and endangered 25 houses on the southern slopes of Nagy Hrabó Mt.. In 1999-2000 the problem was solved here by carrying the water off in tubes and preparing the gutters on the road. Here the movement affected the soil that contains dacite detritus.

Such movements highly depend on different kinds of rainfall. After heavy rains first swelling and then – in the drying phase – shrinking can be observed in rocks with high montmorillonite content. The high montmorillonite content (40%) of covering soil promotes movement in the whole upper 10-15 metres cross-section (Fig. 2). In the rhyolite tuff, tuffite and conglomerate 1-2 centimetres thick hydrothermal quartz veins, opal and chalcedony fillings evidently indicate hydrothermal epigenetic effects.

MORPHOLOGIC FEATURES OF THE SLIDES

Rotational slumps display semicircular, convex, arched, back-tilted surfaces of more 10 metres diameter which are recurred many times towards the movement slope forming whole fronts (Fig. 2.). In the slipped, back-tilted zone in the background there is a small bowl-shaped pond (József Attila Street, NW).

In case of *slumps* along bed surfaces, there are cracks and slides of several metres size on the borders of rock bodies. It may be accompanied by smaller diapiric uplift due to swelling (Hrabó Mt. area).

Bed slides occur along the 20 - 30° steep slopes. On the soapy slip surfaces of bedded rhyolite tuffs and tuffites of high montmorillonite content movement slickensides or – in some cases (in the vicinity of the nursery) – disturbed bedding are developed.

MACRO- AND MICROSCOPIC CHARACTERISATION OF THE ALTERED ROCKS

The formations involved in the mass movements are described below in terms of occurrence, macroscopic features and optical microscopy.

Bentonitic andesite

It can be found near the surface in the sliding area in József Attila Street in the HCS-11 drilling and in shaft III. It is variegated, red-green coloured, soapy and can be cut by hand. Macroscopically 1-2 mm porphyric feldspars and 45° steep, striated sliding surfaces can be observed. Hydrothermal quartz veins of 3 mm diameter cross the rock next to a slip surface dipping at 65°.

According to the microscopic analysis 80% of the groundmass of the hyalopilitic, porphyritic, vesicular andesite has been altered to montmorillonite of 2 – 5 μm grain size. Some of the feldspars contain montmorillonite inside. There is opal and chalcedony filling in the vesicles.

Bentonitic rhyolite tuff

It can be found in an outcrop on the northern end of József Attila Street, on a rotational slump front. The varieties alternating with each other are olive-green, bedded, fine grained perlite, obsidian bearing, sandy bentonitic dust tuff and pumiceous lapilli-bearing rhyolite tuff microconglomerate of 3 – 5 mm in grain size. The rocks can be cut with knife when wet.

The vitreous groundmass of the vitro-crystalloclastic rhyolite tuff became a mass of montmorillonitic grains of 1 – 2 μm size. The fibrous pumice grains of 1000 μm size are slightly devitrified. There are 100 – 200 μm biotite, quartz, sanidine and muscovite crystals and 1000 μm large rhyolite and andesite rock fragments. The pebbles accumulated in aquatic conditions.

Marine clay

The colour is yellow if oxidised, grey in the reduction zone. It is micro-stratified (laminated), plastic when wet, cracked if dried out. It has mosaic structure with shiny sliding surfaces in the movement zone.

Soil ("Nyirok")

The soil called by the local name "nyirok" is fine-grained, granular, and slightly plastic when wet; tough, crumbly, and inhomogeneous. The grains are surrounded by a clay matrix.

MINERALOGICAL ANALYSIS

The primary aim of the mineralogical analysis was to identify the distribution of the swelling clay minerals in the different rocks participating in the mass movements (Table 1).

The montmorillonite contents are higher in the volcanic rocks. This mineral is well crystallised Ca-montmorillonite. The 001 basal reflection has high intensity.

Table 1. Swelling clay mineral contents of rocks (%, average and range).

Formation	montmorillonite	illite/montmorillonite
soil ("nyirok")	29 (20-43)	4 (0-5)
marine sandy clay	24 (12-50)	4 (0-6)
bentonitic rhyolite tuff	52 (34-81)	1 (0-6)
bentonitic andesite	74 (58-91)	-

The montmorillonite in sedimentary rocks has 001 basal reflection of lower intensity and is poorly ordered. In these rocks illite can be observed in higher amounts (Fig. 5).

According to the thermal analysis, the character of montmorillonite is different in different rock types (Fig. 6). The dehydroxilation temperature of the montmorillonite of the rhyolite tuff is 700 °C, which characterise the primary montmorillonite.

The dehydroxilation of the montmorillonite of the bentonitic andesite proceeds in two steps; the first reaction at 530 °C and a second is at 655 °C. The red bentonitic andesite has some kaolinite content too. The Sarmatian marine clay and soil ("nyirok") consist of a mixture of different clay minerals (montmorillonite, illite, chlorite).

The results of the XRD analysis of 15 powdered bulk samples of rocks (Table 2) show the following non-swelling minerals composition:

The mineral composition of the soil and marine sandy clay formations is characterised by higher contents of detrital, inherited minerals and carbonates (muscovite, quartz, feldspars, chlorite, calcite, dolomite).

The argillised volcanic rocks presented similar mineralogical composition, with high contents of cristobalite.

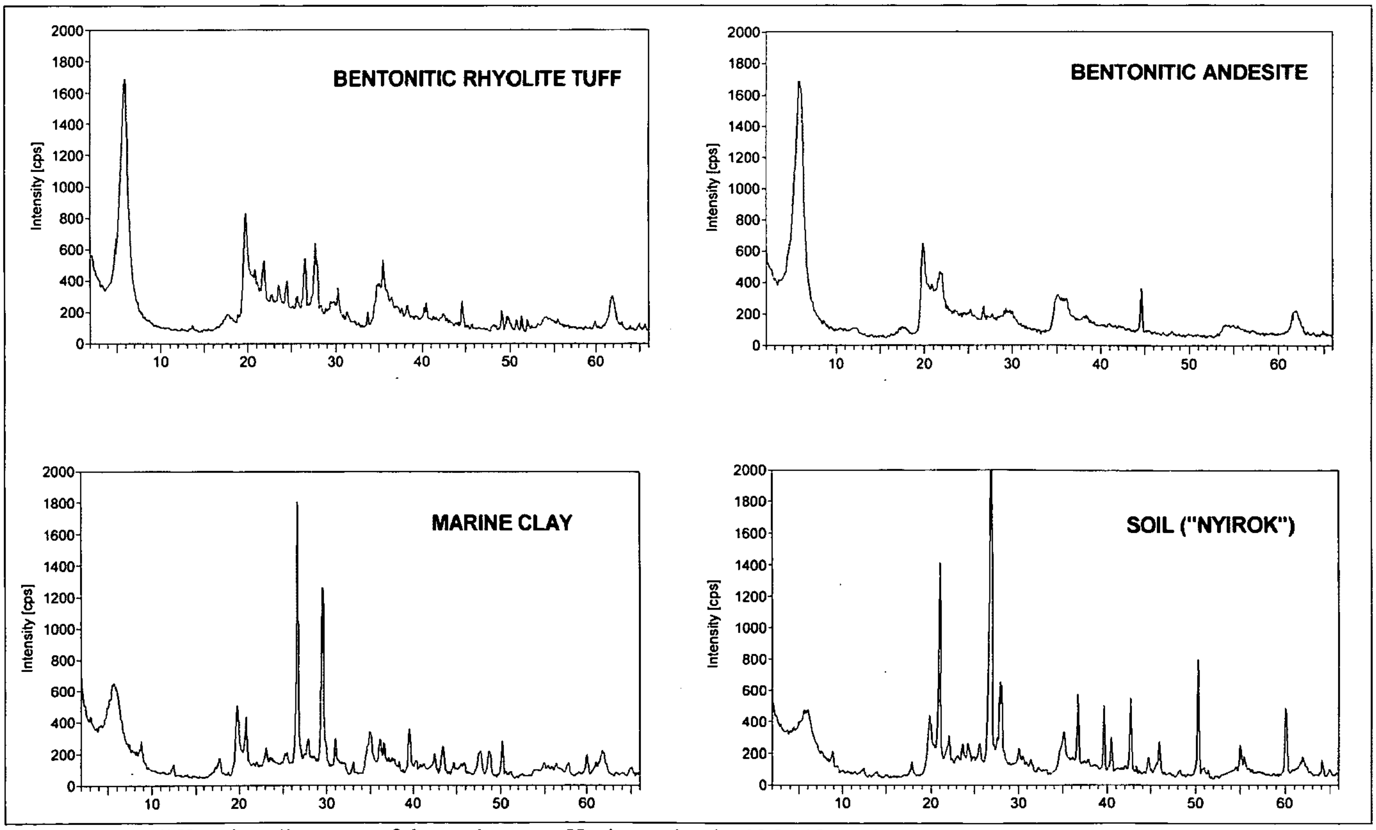

Fig. 5. X-ray diffraction diagrams of the rock types. Horizontal axis: °2Θ, (CuK_α).

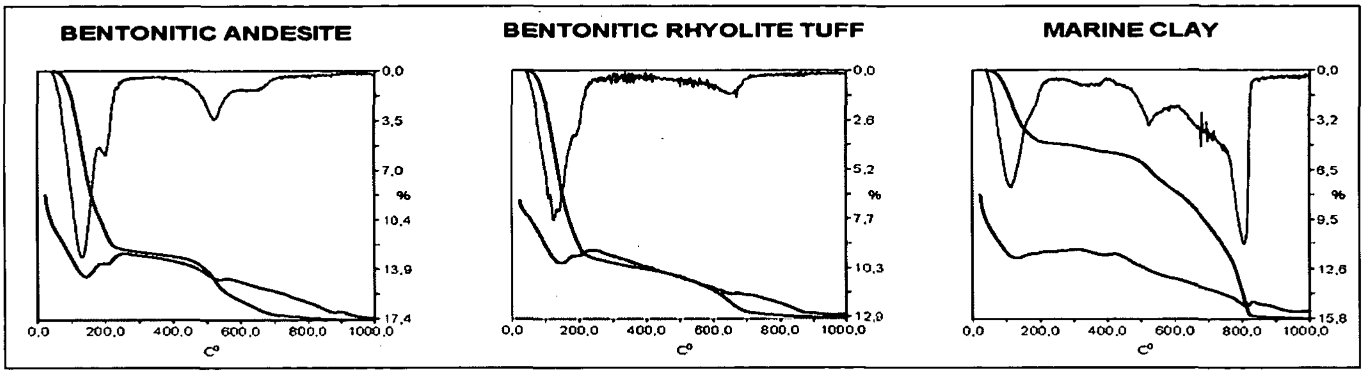

Fig. 6. Thermoanalytical curves of the rock types.

Table 2. Non-swelling mineral contents of rocks (%, average and range).

Formation	muscovite, illite	kaolinite	chlorite	quartz	K-feldspar	plagioclase	cristobalite	calcite	dolomite
soil ("nyirok")	6 (0-12)		4 (0-4)	35 (33-37)	3 (2-4)	7 (6-8)		3 (0-6)	2 (0-4)
marine sandy clay	10 (0-18)	1 (0-3)	4 (0-6)	21 (9-31)	1 (1-2)	3 (0-7)		9 (0-17)	3 (0-7)
bentonitic rhyolite tuff			1 (0-2)	5 (3-8)	1 (1)	7 (5-9)	14 (0-28)		
bentonitic andesite		3 (0-4)		2 (1-4)	1 (0-3)	1 (0-2)	12 (0-22)		

CONCLUSIONS

At Hollóháza the strongly altered rhyolite tuff of different grain size originally fallen into water alternates with Sarmatian marine clays. The covering soil has high expandable clay mineral content, too. These rocks swell due to saturation with water and slides may occur on their surfaces. Andesitic rocks in the basement also became bentonitic, strongly contributing to the occurrence of slumps. Volcanic rocks contain more and well-crystallised montmorillonite. In sedimentary rocks montmorillonite is less and is of disordered type.

The swelling of clay minerals plays an important role in the damaging changes of the surface.

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