LANDSLIDES

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Abstract: *We can define a landslide as the movement of rock, detritus, or soils caused by the action of gravity. It occurs often following torrential rain or earthquake, and even volcanic eruptions can lead to landsliding. Landslides are a major form of geohazard that cause millions of dollars of damage and many deaths each year. The stability of a slope can be considered as two forces working against each other. Driving forces – shear stress work to cause slope materials to move down – slope, whereas resisting forces – shear strength act to keep the materials on the slope. When the ratio of resisting forces over driving forces is greater than 1, the slope is stable. When it is less than 1, the slope usually fails. Earthquakes can instantly change the local force equilibrium, anticipating the fall. The present paper reports on the evidence of the areas affected with landslides. On the basis of the clay minerals analysis are explained the displacement mechanismus from the Bozovici and were given the control methods. If land has moved once, there is a high chance of it moving again given the right conditions. It is therefore imperative to recognize ancient landslides and assist the planning process with maps to raise awareness of their presence prior to building. For whole region Banat, with an area of 1198264ha land resources, the area with landslides represents 5.53%, that is 66335 ha. Rockfall is the movement of a single block. Rock avalanches result from the transformation of rock slide into a deeply disintegrated, rapid, and catastrophic flow of rock. Mass movement (flow) is any process that involves a transfer of slope materials, rocks, debris or soils, from a higher to a lower location under the influence of gravity. Translational slides occur along a failure surface in the bedrock and move parallel to the surface. The landslide from Bozovici affects 42,5 ha. The shrink – swell properties lead to landslide and shifting problems. Significant landslide is solifluction, that is a process of gentle and continous flow on low – gradient sloping land of a thin, viscous, water – satured mass of soil or rock debris. In order to prevent, and mitigating their impact, the need is to reduce the driving forces and/or increase the resisting forces on the slope. Building a buttress at the bottom of the slope by erecting a wall of boulders, building a concrete wall with weep holes, or building a gabion basket wall will increase the resisting forces of the slope.*

Key words: *hazard, vulnerability, friction, cohesion, stability, liquefaction*

INTRODUCTION

We can define a landslide as the movement of rock, detritus, or soils caused by the action of gravity. They can occur at all scales, from a few meters across to several kilometers, and at all rates, from meters per year to meters per second. It occurs often following torrential rain or earthquake, and even volcanic eruptions can lead to landsliding. Usually, distinguished are gravity slides, block slides and rotational slides (deep landslides) and debris slides and landslips – a shallow landslide occurring over only a short distance, composed mainly of debris of earth material, usually saturated with water. Landslides are a major form of geohazard that cause millions of dollars of damage and many deaths each year. Possibly the largest landslide on land occurred some 10.000years ago in south – western Iran [4]. Called the Saidmarreh Landslide a mass of limestone 15km long, 5km wide, and 300m thick slid off the underlying marl bedrock and travelled a distance of 18 km while dropping only 1000m. V. De Blasio [3] mentioned the disaster of the Nevados Huascaran, one of the worst landslide disasters in

historic times. On May 31, 1970, a strong quake shakes the Peruvian Andes, causing the collapse of 50 million cubic meters of rock and ice from the mountin called the Nevados Huascaran. After 500m of free fall, the material collapses against the glacier 511; disintegrating at once, it generates a shock wave, and devastate a large area. The intake of water and ice rapidly transforms the solid material in a debris flow, a lethal and rapid river of dense fluid capable of carrying huge boulders with colossal devastating power. The towns of Yungay and Rahnrahirca are shattered and 8000 of the inhabitants killed.

But the worst landslide disaster in historical times occurred on December 16, 1020 in Kanson, China when over 180000 people were killed. Many of these people were living in homes excavated in or built on the slopes of loess. This soil has a metastable fabric and collapsed an earthquake – triggered event [4].

The stability of a slope can be considered as two forces working against each other. Driving forces – shear stress (a stress acts during a shear process upon a body, such as a soil sample, parallel to the plain on which the force has been applied) work to cause slope materials to move down – slope, whereas resisting forces – shear strength act to keep the materials on the slope. According to the Coulomb equation shearing strength of soils has two components cohesion and internal friction [8]; **cohesion** is a general term for the force of mutual attraction developed between molecules or particles of a body, counteracting any trend of dividing this body into smaller parts, and increases following drying of a soil sample; **internal friction** takes place between different solid particles, of a single body, moving relative to each others, and appears when a shear strain is applied.

When the ratio of resisting forces over driving forces (called the factor of safety) is greater than 1, the slope is stable. When it is less than 1, the slope usually fails. Filling soil pores with water reduces soil strength by increasing pore pressure and reducing the effective stress.

Clay, shale, serpentinite and uncompacted fill are all slope materials prone to failure, having significantly lower angles of reponse.

Change in stability conditions may be consequent to a variety of causes such as river undercutting or ice melting. Earthquakes can instantly change the local force equilibrium, anticipating the fall. The process of mountain building continuously overloads rock masses with renewed stress throughout time scales of several million years. Volcanic eruptions deposit enormous amounts of pyroclastic materials, which may subsequently be mobilized by rain [7]. Owing to the significance in the prevention of disasters, slope stability has been the subject of much effort [6,7,9,10]. There exist numerous numerical models. Textbooks and computer programs for assessing the stability on different kinds of terrain.

MATERIAL AND METHODS

The present paper reports on the evidence of the areas affected with landslides, separates the zones with stabilized, semistabilized and active landslides and makes a morphological, mineralogical, physical and chemical description for some of them. On the basis of the clay minerals analysis are explained the displacement mechanismus from the Bozovici and were given the control methods.

RESULTS AND DISCUSSIONS

Landslides are not only a significant geohazard; they also contribute to the geomorphic reshaping of the landscape and and transforms the local topography, redistributing the material to long distances from the source, landslides should be envisaged as a natural and

common phenomenon in the geological history, but they are rarely perceived as such by the community.

If land has moved once, there is a high chance of it moving again given the right conditions. It is therefore imperative to recognize ancient landslides and assist the planning process with maps to raise awareness of their presence prior to building.

For the district Timi;, we present the situation in table 1 [12]

Table 1

Landslides in Timis – district (OSPA Timis)

No.	Commune	Stabilized	Semistabilized	Active
1	Balinț	607.5	-	-
2	Bârna	789.92	14.84	-
3	Belinț	-	-	14.3
4	Bethausen	320.5	270	185.2
5	Brestovăț	4338.25	-	4
6	Boldur	41.5	-	-
7	Bogda*	2881.79	-	-
8	Buziaș	198.5	-	-
9	Cosava*	456	385	263
10	Coștei	693.4	1309.42	100.78
11	Criciova	1451.3	872	1014.2
12	Curtea	177.41	11.44	-
13	Darova	186.8	-	-
14	Delamarina	2052.95	-	363.5
15	Dumbrava	232.8	187	134.5
16	Făget*	912.2	-	-
17	Fârdea	524.3	231.5	294.2
18	Gătaia	485	320	217.2
19	Giarmata	25.89	-	-
20	Ghizela	476	-	-
21	Jamu Mare	147.47	92.74	-
22	Lugoj	328.2	281.4	138.7
23	Mașloc	690.7	-	-
24	Margina	54.05	7	102.74
25	Mănăștiur	305.2	241	173.8
26	Nadrag	106.45	2.75	9.4
27	Nitchidorf	136.2	82.7	54
28	Ohaba Lungă	1640.2	1012.7	864
29	Pietroasa	863.6	421.3	322.8
30	Pischia*	230	-	-
31	Recaș	3165.63	-	15.22
32	Remetea Mare	219	131	87.5
33	Racovița	-	-	5.9
34	Satchinez*	392	-	-
35	Secaș	3047.74	-	202
36	Știuca	1595.42	62.49	617.36

37	Tomeşti	-	1393.1	-
38	Topolovăţu Mare	531.85	-	-
39	Tormac	319.5	191.4	127.6
40	Traian Vuia	315.2	264.5	187.2
TOTAL		30940.42	7785.28	5504.5

* - estimative values

For whole region Banat, with an area of 1198264ha land resources, the area with landslides represents 5.53%, that is 66335 ha (table 2)

Table 2

Landslides in Banat, ha

District	Stabilized	Semistabilized	Active
Caras-Severin	12618	6106	3381
Timis	30940	7785	5505
TOTAL	43558	13891	8886

Landslides are generally classified into process groups based on their rates of movement and corresponding amounts of water contained within the landslides mass [4].

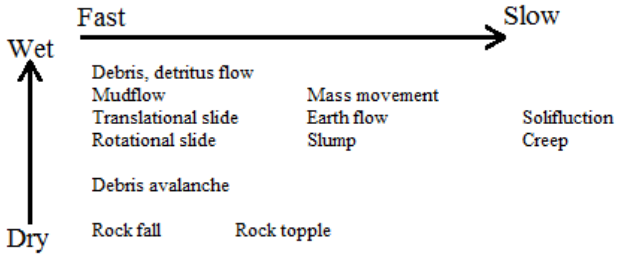


Figure 1 *Landslides classification* (modified after Burns [4])

Rockfall is the movement of a single block. The product of rockfalls often appers as a rock heap, a talus, at the foot of mountain slopes. Rockfalls are a significant safety problem in mountainous areas, as single falling boulders may kill people, interrupt roads and railways, and demolish buildings.

Rock avalanches result from the transformation of rock slide into a deeply disintegrated, rapid, and catastrophic flow of rock. They may involve volumes of the order of several cubic kilometers and reach velocities higher than 100km/h.

Mass movement (flow) is any process that involves a transfer of slope materials, rocks, debris or soils, from a higher to a lower location under, the influence of gravity, without the primary assistance of a fluid transporting agent. There are several regions in the world at risk for volcanic mud flows, otherwise known as **lahars**. These flows are composed of a mixture of clay, silt, water, and coarse material like large blocks. Wet mixtures of soils with clast size from lay to boulders are known with the generic name of debris flows.

Rocktopple is a type of rock displacement where there is forward movement of a block rotating around a fixed hinge. Toppling is very common in basalt cliffs where columnar jointing is present.

Translational slides occur along a failure surface in the bedrock and move parallel to the surface. The failure surfaces upon which such landslides move are generally clay layers, shale layers, or palaeosoils. Such landslides are in district Caraş-Severin, in the perimeter from

Bozovici, Dalboșeț, Bocșa, Forotic, Obreja, Domașnea. In this paper we present the results of soil mineralogica land chemical analysis (table 3). The landslide from Bozovici affects 42,5 ha.

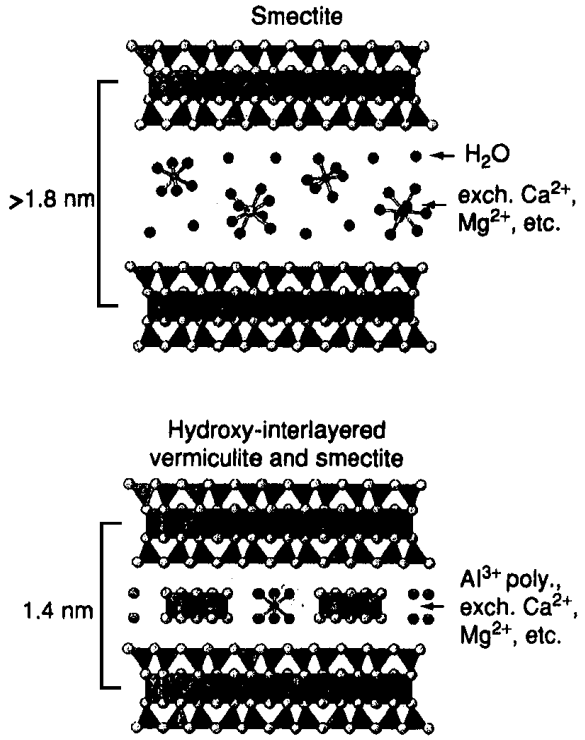
Table 3

Chemical and mineralogical analysis Bozovici

Soil sample, depth, cm / Analysis	Steep detachment			Slidemass
	10-30	**40-50**	**150cm**	**20-40**
Clay, %	47.7	49.6	57.2	54.7
pH_{H2O}	7.07	8.22	7.92	7.72
$CaCO_3$, %	1.08	6.46	5.38	8.94
Humus, %	1.60	1.71	2.16	1.16
Clay minerals				
% from clay				
- smectite	85	64	75	85
- illite	10	20	16	11
- caolinite	5	16	9	4
% from soil				
- smectite	40.3	31.8	43.0	46.5
- illite	4.6	9.7	9.0	6.0
- caolinite	2.8	8.0	5.1	2.1

The smectite group consists of mineral with the 2:1 structure similar with mica and vermiculite, but with a still lower charge per formula weight, namely 0.6-0.2 (fig.2). As in vermiculite, the interlayer contains exchangeable cations. The formula for a common soil smectite, the mineral beidellite, is $M^{+}_{0.33}Al_2(Si_{3.67}Al_{033})O_{10}(OH)_2$ were M^+ represents exchangeable cations, typically Ca^{2+} and Mg^{2+}.

The most common smectite minerals range in composition between three end – members: montmorillonite, beidellite, and nontronite. Smectites shrink upon drying and swell upon wetting. The shrink – swell properties lead to landslide and shifting problems.



If the sliding mass occurs along a curved – upward and shows rotation, it is called a **rotational slide**, which may develop into a **slump** if the integrity of the failed mass is destroyed. Such movements are common in mudstones and clay soils.

Significant landslide is **solifluction**, that is a process of gentle and continous flow on low – gradient sloping land of a thin, viscous, water – satured mass of soil or rock debris. It often follows thawing of the surface layer and takes place over the still frozen lower layer.

A slow mass movement of soil and soil material downwards from a steep slope, primarly under the influence of gravity is called, creep. It is facilitated, by soil saturation with water and by alternate freezing and thawing or wetting and drying. The rates are in the range from 0.1 to 100 $mm.yr^{-1}$.

In order to prevent, and mitigating their impact, the need is to reduce the driving forces and/or increase the resisting forces on the slope. Decreasing the slope angle will significantly increase stability. Removing water from the slope through drains will decrease the driving forces and increase the resisting forces. Building a buttress at the bottom of the slope by erecting a wall of boulders, building a concrete wall with weep holes, or building a gabion basket wall will increase the resisting forces of the slope. In rockfall – prone areas the use of screens or sprayed – on shotcrete will keep the rock fragments.

CONCLUSIONS

A landslide is a movement of rock, detritus, or soils caused by the action of gravity. To distinguish landslides from other forms of gravity mass flows, we require in the definition that the bulk of the moving material should have density at least 10% greater that the density of water. A landslide starts as consequence of terrain instability, and for this reason it is important

in geotechnical practice to ascertain the stability conditions of soils or rocks. The most common landslides in Banat are the mass movement, like solifluction and slump and creep. The areas occupied with landslides represent 5.53% (66.335 ha). The mass movement is favorized of the smectite dominant in the clay composition (64 – 85%). It is imperative necessary to prevent the landslides and increase the slope stability.

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